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PROCEEDINGS

OF

THE ENGINEER'S CLUB

OF

PHILADELPHIA

VOLUME XXIII

EDITED BY THE PUBLICATION COMMITTEE

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PAPER NO. 1015.

SAND-LIME BRICK.

E. W. LAZELL.

Read November 4, 1905.

THIS industry can properly be called the artificial stone industry and was originally developed in Germany. The stone or brick was first made from mortar and was produced in the same manner as ordinary mortar, that is, by mixing lime and sand in the correct proportions. The hardening agent in this case was the carbon-dioxide of the atmosphere; the method was tedious and months were required to produce a good article. The strength of the brick, however, increased with age. In this class of bricks the lime acted only as a mechanical binder, uniting and binding together the particles of sand by means of the carbonate of lime which surrounded and inclosed them.

Later, in the development of the industry, artificial means of hardening the products were introduced, chief of which is the hardening by steam. To distinguish the material made in this manner from that hardened by carbon-dioxide it is often called the silico-calcareous compound. While in the case of hardening by carbon-dioxide weeks and months are required to produce a good article, in the latter method only a few hours are required.

The method of manufacturing sand-lime brick can be divided into classes "A" and "B":

"A." Those in which the hardening is due wholly to the formation of calcium carbonate; under this heading come:

1. Those bricks made from lime and sand which are allowed to harden in the atmosphere.

2. Where the hardening is brought about by exposing the bricks to an atmosphere rich in carbon-dioxide, by which the formation of the carbonate is accelerated, thus giving the same results as by method No. 1, only in less time.

3. By hardening with carbon-dioxide under pressure. The exponents of this process claim that nearly all the lime is converted into the carbonate. This, however, would seem hardly possible.

"B." Those products in which the hardening agent is steam; this class of bricks is spoken of as silico-calcareous compound, and can be further subdivided into:

1. Those products hardened by steam under atmospheric pressure.

2. Those products hardened by steam at a high pressure. This second class comprises the only products used to any extent in this country, and will be most fully dealt with in this paper.

This process was first developed about 1880 by Michealis, who discovered that steam under pressure brought about a hardening of the product. This has been explained by a chemical reaction taking place between the hydrated lime and the sand, resulting in the formation of a hydro-silicate which forms the binding material of the brick. This assumption, however, while generally quoted, has had no experimental demonstration, and no proofs have been brought forward as to the presence of a hydrated lime silicate in the material.

The industry was introduced in the United States in 1901 by Mr. F. Ohlemacker, who erected a factory for the manufacture of sand-lime brick at Michigan City, Indiana. In the few years since the introduction of the industry it has rapidly increased, until at the present time there are about 140 plants in operation in this country with a yearly output of 400,000,000.

Before taking up more fully the method of manufacture and the uses, it will be well to look more closely at the materials used in making the bricks, that is, the sand and the lime.

Sand.

Almost any sand can be used and a fair product obtained if the treatment is properly varied to suit the material. For a cheap and successful manufacture it has been found that a comparatively pure sand is essential; that this material should be so graded from coarse to fine that it contains the minimum voids.

In order that the amount of lime used should be as low as possible, the sand should contain sufficient small particles to fill the interstices; these small particles, owing to their greater surface, are more easily attacked by the lime. A small percentage of clay in the sand does not apparently injure the product, and some manufacturers consider 5 per cent. advantageous, as it renders the material more easily molded.

River or bank sand is most commonly used in the United States, and if this does not contain sufficient fine material, it is customary to grind a portion of it, thus obtaining by mechanical means the required percentage of fine material. Crushed quartz or crushed siliceous sandstone can also be successfully used.

Lime.

The first requirement for the lime is proper burning. It should be thoroughly burned so as to have no unburned core, but in no case should it be overburned, because of the length of time required to slake overburned particles.

The second requirement is the thorough hydration of the lime, since if any unhydrated particles are present, these will later expand in the steam treatment and rupture the brick.

At the present time the fat or high calcium limes are almost wholly used in making the silico-calcareous products; this is probably due to their more rapid and complete hydration than the Dolometic limes. With proper care and treatment, however, the magnesium limes can be used with good results.

There are in practical use three methods of preparing the lime for these products:

1. The oldest method is by slaking the lime to the consistency of a thick paste and mixing the sand with it in this condition. This method has the advantage of thorough hydration, especially if the material is stored some time before its use and the mixture works easily in the press. These two advantages, however, are more than offset by the difficulty in getting a thorough mixture of the lime paste and the sand. This method is almost wholly used for making bricks of class "A," in which the hardening agent is carbon-dioxide. If the bricks are to be air-hardened, it is the general custom to use hydraulic lime to give an initial hardening. Bricks have been successfully manufactured by this process in Switzerland.

2. By using dry hydrated lime in place of the lime paste. This material is obtained by adding sufficient water to the quicklime for its

complete hydration and by carefully avoiding any excess. By this method the lime falls to a very fine white powder which is more readily mixed with the sand. It is, however, necessary to store the lime so prepared for some time in order to assure complete hydration, and to remove by sieving or air separation, as far as possible, any unslaked particles, since these would afterward slake in the process of manufacture and rupture the bricks. Later, in order to facilitate the molding, sufficient water must be added to the mixture of the lime and sand to produce a plastic mass.

3. The third method is by the use of ground quicklime, and slaking this in contact with the sand, it being claimed for this process that the heat developed in slaking increases the formation of the hydrocalcium silicate. This process was developed by Swarz in Switzerland.

Manufacture.

Since the manufacture of those products in which the hardening agent is carbon-dioxide is not carried on in this country, we will deal only with the methods involving the hardening by steam. The first step in the manufacture must be the thorough mixing of the sand with whatever form of lime is used; this is generally accomplished by some mechanical means, such as mixing screws, pug mills, mixing pans, or other device. It is the general practice to dry the sand before mixing with the lime in order to be able to control the amount of moisture in the resulting product. This is necessary because of the great variations in the amount of water in the sand, due to the weather. The sand is delivered from the dryer to the storage bin, and the lime in a similar manner is delivered to another storage bin. In case hydrated lime is used the bin capacity should be great enough to allow the lime to be stored some time before being used.

The most common method in use in this country is to use dry hydrated lime; the sand and lime are weighed and delivered to a mechanical mixer in which sufficient moisture is introduced to give a degree of plasticity to the mass in order that it may be easily handled in the brick presses. From the mixing machine the material goes directly to the presses, where the bricks are manufactured in the same manner as ordinary repressed bricks. From the presses the bricks are piled up on cars and are placed in a hardening cylinder. This hardening cylinder is nothing more than a steel tunnel made of boiler plate with removable tight ends containing a track upon which the cars of brick can be moved. Live steam under pressure is introduced to this tunnel and

brings about the reaction between the lime and sand which results in the hardening of the brick. In this tunnel or hardening cylinder the bricks are subjected to pressure for from six to twelve hours; the length of time that they must be cured in the hardening cylinder depends upon the materials and the pressure used. With a pressure of 120 pounds ten hours is generally sufficient.

Since in this process the supposed object is the formation of the maximum amount of the hardened compounds or hydrosilicate, no more lime should be used than will react with the sand. An excess of lime would result in the presence of uncombined hydrated lime, which would be detrimental to the product. The amount of lime used varies in different work, but generally is between 5 per cent. and 10 per cent.

As soon as the bricks are taken from the hardening cylinder they are ready for shipment. The entire transaction from the time the sand and lime are prepared until the finished brick is ready for shipment does not require more than twenty-four hours.

These different methods of manufacture have been introduced in this country, and I will give a brief outline of each:

Huenneke's System.—The sand and the quicklime are ground together in a tube mill, then slaked, and the mixture stored in bins for twelve to twenty-four hours before going to the presses to be molded. In the hardening cylinder some chemicals are added in order to aid the combination of lime and sand.

American and Kommick Systems.—These are very similar, and will be described as one. In this system the lime is hydrated in pans by steam under pressure in the same cylinder that the bricks are hardened in. The hydrated lime is then ground and mixed with the sand.

Swarz System.—The sand is first introduced into a specially designed drum which is jacketed and heated by steam and the moisture is completely removed by means of a vacuum. The lime is then introduced into the machine and the mixing is performed under the vacuum. After a while the necessary degree of moisture is introduced in the form of steam by a special arrangement of pipes; the mixture is finally emptied into a storage bin and delivered to the press still warm.

Uses.

This new building material which has been made in this country for the past few years and which has shown a phenomenal growth is worthy of the careful consideration of architects and engineers. The

bricks in their natural state resemble Indiana sandstone in appearance, and their method of manufacture, to a certain extent, is a reproduction of nature's process. They are, however, different from the natural stones in that they possess a greater uniformity and freedom from seams or laminations. The bricks are made as cheaply as ordinary face clay bricks, and possess a much greater uniformity in regard to both their strength and appearance.

The tests of sand-lime bricks show their uniformity in regard to both crushing and modulus of rupture; the bricks are well adapted for use as face bricks owing to their great uniformity in regard to both color and shape. Further, almost any desired color can be obtained by the use of mineral oxides without decreasing the strength of the bricks.

A peculiarity of these bricks is that when they have been subjected to alternate freezings and thawings or wettings and dryings their strength is increased.

Manufacturers claim the following advantages of the sand-lime bricks over those of the clay products:

1. They improve with age.
2. The bricks are more uniform in size, shape, and color.
3. Uniform and high compressive strength.
4. Uniform and high tensile strength.
5. Low porosity.
6. No efflorescence.
7. They are unaffected by atmospheric changes.
8. No disintegration by freezing.
9. Great resistance to the action of fire.
10. Poor conductors of heat and electricity.

Tests.

The results of the tests made on these bricks are best shown by the tables. The crushing strength of the natural colored brick is generally about 3,000 pounds per square inch. The average modulus of rupture figured by the formula $R=\frac{3}{2}\frac{Wl}{bd^2}$, in which the distance between the supports is seven inches and the weight is applied in the center,—the bricks being placed flatwise,—is 420 pounds. The average absorption as shown by tests in our laboratory varies between 5 per cent. and 14 per cent., the loss in weight by exposing the bricks to ten alternate freezings and thawings is less than one-half of one per cent., and the crushing strength of the brick is increased by these freezings.

In one of the tables are the results of tests made on sand-lime brick collected from a manufacturer near Philadelphia, and for comparison tests are given of common clay brick, hard-burned brick, repressed brick, and Indiana sandstone. All of these samples were procured in the open market and represent average products. Further, I have tabulated tests made on sand-lime bricks and other bricks by recognized authorities. In all these tests the sand-lime bricks show up well; their fire-resisting quality is very good and they do not check or spall under the action of heat or water, and show signs of calcination only on the surface after a long exposure to intense heat.

The writer understands that tests are to be made in New York as to the fire-resisting quality of this material. Buildings made from sand-lime bricks have been exposed to the action of fierce fires in Germany without any signs of injury.

COMPARATIVE TABLE SHOWING TESTS OF SAND-LIME BRICK AND CLAY BRICK COMPILED FROM PUBLISHED RESULTS.

	Crushing.	$R = \frac{3Wl}{2bd^2}$	Absorption.	Made by:
Sand-lime brick,	2097 3210	635	11.0 10.9	Prof. A. Marston, Iowa State College.
Average, six varieties of common brick,	3370	660	15.7	Prof. A. Marston, Iowa State College.
Average, three varieties of salmon brick,	1850	300	20.8	Prof. A. Marston, Iowa State College.
Common building brick, hard-burned,	3943	499	15.3	Prof. Ira Woolson, Columbia.
Sand-lime brick,	3848	....	10.5	Pittsburg Testing Laboratory.
Sand-lime brick,	4000	1000	....	Prof. Ira Woolson.
Philadelphia common brick,	1300	350	....	Prof. Ira Woolson.
Philadelphia stretcher brick,	3500	500	....	Prof. Ira Woolson.

COMPARATIVE TABLE SHOWING STRENGTH OF SAND-LIME BRICK, CLAY BRICK, AND SANDSTONE COMPILED FROM TESTS MADE IN THE LABORATORIES OF THE HENRY S. SPACKMAN ENGINEERING CO.

Material.	Crushing, Lbs. Per Sq. In.	Transverse Mod. of Rup. $R = \frac{3Wl}{2bd^2}$	Absorption Per Cent.	Crushing Wet after Absorption, Lbs. per Sq. In.	Freezing, Loss in Weight (Per Cent.).	Crushing after Freezing, Lbs. per Sq. In.	
Sand-lime brick, common.	Aver., 2718 Max., 3035 Min., 2136	....	15.07	1699 1826 1459	0.41	3023 3067 2956	Sample from lot of 300,000, natural color.
Sand-lime brick, face.	6025	....	12.87	3958	0.20	6765	6,000, brown color.
Sand-lime brick, common.	Aver., 3014 Max., 4000 Min., 2100	420	14.00	....	....	....	Average 200—S.-L. B. tests.
Clay brick, common.	Aver., 2325 Max., 2587 Min., 1891	....	16.65	1917 2145 1702	0.74	2216 2550 1875	....
Clay brick, hard-burned.	Aver., 4288 Max., 4494 Min., 3976	....	9.15	4633 5564 3975	0.18	4577 4864 4056	....
Clay brick, repressed front.	Aver., 4469 Max., 5108 Min., 3885	....	10.71	4431 5103 3807	0.22	4566 4937 4097	....
Indiana sandstone.	4152	....	5.65	....	0.37	5561	....

DISCUSSION.

E. W. Lazell.—The temperature employed in the steam cylinder for hardening the bricks is that corresponding to 150 pounds steam pressure, or about 350° F.

The increase in strength of the bricks as the result of being frozen is probably accounted for in the gradual change of the hydrated lime in the brick to carbonated lime, due to the pressure of carbon-dioxide in the water used in thawing out the bricks.

I do not know of any tests having been made in this country as to the fire-resisting quality of the bricks. Prof. Woolson is about to make such a test in New York. A number of tests have been made in Germany and the bricks behaved very well. The tests tabulated in the paper were made on bricks of different ages. Some were over a year old and the samples were taken in winter, the bricks being frozen in the pile. In the column giving the averages of two hundred sand-lime brick tests the majority were not more than two days old. In the tests the clay bricks were faced with plaster Paris on the machine before being broken, and the sand-lime bricks were crushed with felt or blotting paper between the surface of the machine and the brick. The bricks subjected to compression were half bricks, and were the same that had been used in the cross-breaking tests. The mortar joint between bricks as laid in a wall acts simply as a cushion; the setting of this mortar is due to drying out and to the slow formation of calcium carbonate.

William Copeland Furber.—In comparative tests of crushing strength the method of bedding the specimens is very important. Some years ago when the fever for cement brick was in the air a number of Philadelphians were invited by the Atlantic City Cement Brick Company to inspect their plant, and they showed some remarkable results in tests of the crushing strength of their brick as compared with common hard clay brick. A little investigation revealed that the reason for the apparent superiority of the cement brick was the fact that they had an approximately true bed while the clay brick had a rough bed, and the crushing test of the latter was really more of a transverse test. When the clay bricks were given a true surface their resistance was very much increased and was much higher than that of the cement brick.

Mr. Bergessen.—In regard to the fireproof qualities of sand-lime bricks we have samples which were placed in a kiln of the Mitchell Fire Brick Company of St. Louis, which showed no change of form after withstanding the heat of the kiln for eight days, and the practice in the plants built by the Schwarz System Brick Company is to line the boilers with these bricks, and they stand well; but it is not claimed that they are more than ordinary building brick. In several instances where fires have occurred in buildings built of sand-lime bricks the results have shown greater resistance to heat than ordinary clay bricks.

Paper No. 1016.

SEWAGE PURIFICATION, WITH NOTES ON ENGLISH AND GERMAN WORKS.

CHARLES F. MEBUS.

Read December 2, 1905.

In his "Notes on the Bradford Sewage Problem" Mr. E. J. Smith truly says: "Public health, natural beauty, and trade cannot be maintained apart from the treatment of sewage, which constitutes one of the most costly, complex, and difficult problems of the age." This fact is, I believe, not appreciated in this country as it should be, but the public mind is being rapidly educated on sanitary matters, and a number of states (with Massachusetts far in the lead) through their Boards of Health are giving sewage purification much attention.

Our own State, great as it is in many things, had not until this year taken even a perfunctory interest in keeping the sewage of cities, towns, and private establishments out of her streams, many of which are used as sources of water-supply. The last legislature, however, passed an Act creating a new Department of Health, which has ample authority and sufficient means to protect our streams from pollution. And I feel sure that this Department will soon adopt the very best sanitary regulations for protecting the health and lives of the people of this State, and further will see that the regulations are enforced.

In England sewage purification works were started as early as 1859, when filtration tanks were constructed in Birmingham. (See Baker's "British Sewage Works.")

In 1876 Parliament passed the Rivers Pollution Act, and since then serious thought has been given to this subject. The Royal Commission, however, complains that although the act has been on the statute book for almost thirty years, a number of towns are still without sewage works, yet to an American it seems as though every town must be treating its sewage, since one sees works of some description all over, when traveling through the country on the fast English trains.

During the time that sewage purification works have been in operation in England, almost every possible scheme has been tried. The national government has done nothing beyond appointing a Royal

Commission on Sewage Disposal in 1898, which thus far has not made its final report, although, according to the London Daily Chronicle, September 23, 1905, £5720 have been expended and £5842 more asked for in 1904.

The experimenting, therefore, had to be done by the municipal corporations themselves, which meant, of course, that many engineers, chemists, bacteriologists, and others were working at the same time on the same problem, differentiated only by local conditions, and giving as a result, naturally, a number of different schemes as well as bringing out many experts.

Many of the earlier works employed chemical precipitation with subsequent land treatment of both the sewage and sludge. This scheme worked very well where the land was of the required sandy nature, and it is still used with most excellent results, as will be seen later. Suitable land, however, was not always available, and even when it was the price was often prohibitive. Other means were therefore sought after, and methods of purification within the last ten or more years have been greatly changed.

The disadvantages of the chemical precipitation with subsequent land treatment are principally two: first, as has been mentioned, the great amount of land it takes; and, second, the treatment of the sludge. Experiments and observations made by chemists and others seemed to show that sewage could be successfully purified on a much smaller area than is required for land treatment, and that the sludge problem could also be solved by merely making provision to develop properly the micro-organisms in the sewage.

Bacterial purification may be said to take place in practically two stages: the first, decomposition and denitrification in septic or sedimentation tanks or anaerobic filters; the second, nitrification and oxidation in contact beds, sprinklers, and intermittent filters. (See "Engineering News," Jan. 12, 1905, Newman's "Bacteriology and the Public Health," and Rideal on "Sewage.") The process is apparently very simple and easy enough in application where sewage consists mainly of household wastes, but for manufacturing cities where the character of the sewage is changed by the introduction of trade wastes, the problem becomes more complex, and bacterial purification may not always give the best results.

When in England I merely tried to study the workings of plants that were in a sense typical or had some special point of interest to commend them, and through the kindness of Dr. Rideal and Mr.

Easdale, both of London, I was directed to works of this character. What we call sewage disposal plants, or, better, "sewage purification plants," are known in England merely as "sewage works."

In England cities are generally sewered on the combined system, and the Local Government Boards insist invariably that works must provide for treating a flow equal to three times the dry-weather flow, and making also special provision by additional beds for an excess storm-water flow equal to six times the dry-weather flow. More than this is admitted to streams without treatment.

Sewage works may be divided roughly into two classes: first, works which employ chemical precipitation with or without subsequent land treatment of both sewage and sludge; second, works employing no chemicals.

Under class 1 come London, Richmond, Guildford, some of the Bradford works, and many others.

In London, at Barking and Crossness, the sewage is merely chemically precipitated, then run through sedimentation tanks, and the clarified effluent passes into the Thames. The sludge is pumped into tank steamers and taken out to sea. Two and one-half million tons of sludge are thus annually disposed of.

At Richmond, in London, near the famous Kew Gardens, the sewage first passes through a screen chamber, from which it is pumped into a channel supplying the sedimentation tanks, and on the way to these tanks it is automatically mixed with a solution of lime and again with a solution of aluminum. The clarified sewage flows from the sedimentation tanks to filter-beds grown over with grass and then to the Thames. The sludge is drawn off and pumped into presses (under a pressure of 100 pounds per square inch), after having been first mixed with lime in proportions of one in twenty. Sludge cake is given to farmers, who are not very eager to get it. There is also a new double contact bacterial plant which will be referred to later.

At Guildford, 26 miles from London, on the Wey River, a tributary of the Thames, above the Hampton Waterworks, is a typical old-time chemical precipitation works with land treatment. This town has about 24,000 inhabitants. The dry-weather flow of sewage is approximately 500,000 imperial gallons in twenty-four hours, one-half of which is trade effluent, principally from breweries. Sewage is pumped from a collecting well to a channel supplying the sedimentation tanks. In this channel is supported a cake of alumnio-ferric, which precipitates the solids. While running through the channel

the sewage passes through an endless-chain revolving screen which is mechanically cleaned by a revolving brush. The sewage then passes into rectangular sedimentation tanks, and the clarified sewage afterward flows over sandy land which has been underdrained by drain tiles laid 100 feet center to center and about 6 feet deep. The effluent from the land is very clear. It is collected by an intercepting sewer which discharges into the Wey River. The sludge is drawn from the sedimentation tanks to a sludge well and then pumped every other day through a line approximately three-fourths of a mile to a field specially ridged and furrowed, and there allowed to dry. The sludge fields are afterward plowed and seeded with rye grass. Mangolds are also grown. The original farm was 70 acres, but 300 more have recently been bought, so that this plant will doubtless remain a chemical precipitation plant for years to come.

A series of contact beds are also in use, and I shall refer to these later.

The effluent from Richmond and Guildford is inspected frequently by the Thames Conservancy Board.

At Bradford the main works, which are at Frizinghall, employ chemical precipitation without subsequent land treatment. Bradford is a great woolen manufacturing city. It has a population of 280,000. The Frizinghall works treat the sewage for a population of 236,000 only. The entire Bradford works are in charge of Mr. Joseph Garfield, Assoc. M. I. C. E. At these works the sewage flows from two sewers into a grit chamber and is automatically screened. The discharge from one of these sewers looks much like Cobb's Creek at Baltimore Avenue. It is precipitated with sulphuric acid and runs through sedimentation tanks having a capacity of one-fourth the daily flow, and from the tanks the clarified sewage passes into the Bradford Beck (Yorkshire term for "creek"). Purification is 50 per cent. The sludge is drawn from the sedimentation tanks and forced by a ram into a vat which is heated by steam. From this vat the sludge is pumped at the temperature of boiling water into the presses. By this means 20 per cent. of the grease is extracted. The grease is collected and again heated, put into barrels, and shipped to America. The revenue from this source amounted to about £6000 in 1904, less than one-half of the cost of the sulphuric acid. The pressed sludge is, at present, mixed with coal (7 to 1) and burned by the aid of forced draught under the boilers which generate the

steam to operate the works. The sludge pressing room is the largest in the world.

A new plant for extracting the residue of grease from the pressed cake by distillation has recently been constructed according to plans of Mr. Garfield, but is not yet in operation.

Bradford has recently acquired some 1700 acres for sewage works purposes, and will in the future combine here all the works, of which there are now ten in different parts of the city, several of them bacterial. At Frizinghall there are also a number of experimental bacterial schemes.

Bacterial Works.

Many chemical precipitation works have been superseded by bacterial works. Bacterial methods of purification may be roughly divided into two classes: viz., (*a*) works using contact beds; (*b*) works using sprinklers.

Contact beds are, again, of three kinds: viz., single, double, and triple contact. Preliminary to treatment on contact beds sewage of course passes through sedimentation or septic tanks.

The almost uniform practice in England is first to screen the sewage, then run it through one or more grit chambers, and follow with the bacterial treatment in the sedimentation tanks.

The grit chambers are regularly cleaned, and the sludge is either treated with the sludge from sedimentation tanks or spread on land.

The sedimentation or septic tanks are always rectangular in plan, the longer dimension being generally from 100 to 350 feet, and the depth from 6 to 10 feet. Such tanks were not infrequently used as sedimentation tanks when chemical precipitation was the prevailing method of treatment.

Single Contact.

The largest and most famous works using single contact are at Manchester, where 92 acres of single contact beds are now in daily use with additional 26 acres of beds for storm water.

Manchester is the cotton market of England. Its population is 525,000 and the dry-weather flow of sewage is approximately 30,000,000 imperial gallons daily. The sewage works are at Davyhulme and Carrington on the ship canal.

The sewage first flows through revolving self-cleansing screens and through a grit chamber which is cleaned daily by means of buckets on endless chains unloading directly into iron cars. Next comes

the treatment in the sedimentation tanks as described above. The capacity of the tanks is such as to give about twelve hours' flow through tanks for the average dry-weather flow. The tanks are regularly emptied, the sludge drawn off and forced through 32 feet of elevation by means of Shone ejectors to sludge tanks near the ship canal. Here the sludge runs by gravity into a tank steamer which carries it out to sea.

The contact beds are ½ acre in size, about 3 feet deep, and are filled on an average twice in twenty-four hours. It takes one hour to fill, one hour contact, and another hour to empty, giving a resting period of nine hours for each filling. Material used in beds is generally boiler cinders out of which has been screened all material under ¼ inch in size. The sewage flows over beds by means of furrows running radially from the inlet valve, here called "grips." When the tops of the beds get slimy, the cinders are forked over and the grips remade. Material for filling costs approximately 3 shillings per cubic yard in the beds. It is thought the beds will have a life of about five years, when an additional 2 shillings per cubic yard will have to be expended in digging up, screening, and refilling. Such work is now in progress at Burnley.

Effluent from contact beds contains some suspended matter. The Mersey-Irwell Board's standard is one grain of oxygen consumed in four hours per gallon.

The beds, channels, tanks, etc., are constructed of concrete. The rate of filtration is less than 500,000 imperial gallons per acre per day. About 2,000,000 imperial gallons are also daily treated by second contact. The chemist in charge, Mr. Arden, is of the opinion that secondary beds should be operated more like water filters than contact beds.

Another single contact works of large size is at Oldham, whose population is 140,000. Here there are over ten acres of beds. The flow of sewage varies from 14,000,000 to 24,440,000 gallons per twenty-four hours. The general scheme is the same as at Manchester. The works were started in 1894 as a chemical precipitation works. The sedimentation tanks are the same as used by chemical works. There are twelve tanks 128 × 36 × 6 feet. One of these is covered, and Dr. Wilkinson, who has charge of the works, is of the opinion that the covered tank has no advantage over the others. The sedimentation tanks are cleaned about four times in a year and contain each time about two feet of sludge. The cost of treatment in 1904 was $12,000 approximately, or $7.00 per million gallons. The sludge is

deposited in a ravine. No concrete is used in the construction except for the tanks. The soil is impervious and therefore nothing is done but to plank the side walls of the beds.

Underdraining is done by terra-cotta pipes perforated on the upper half. These drains are turned up on the side walls of the beds and act as ventilators. The sewage carriers and distributors are of wood.

Contact is longer than at Manchester—in fact, it is about three times as long. The beds are three feet deep and filled with clinkers from the city's refuse destructor out of which all under ½ inch has been screened. The works seem to be very well and economically operated and give good results.

The standard for effluent is the same as at Manchester. Here, as at all the larger works, a chemist is regularly employed and the effluent is tested daily.

Another single contact works is at Exeter, where was originated the "septic tank system" by Mr. Cameron. These works are kept in splendid order, and any one not knowing otherwise would think that it was a flower garden instead of a sewage works. Beds are operated automatically by Cameron's apparatus. The septic tanks are covered, and it is worth noting that on the old tank is placed an ordinary street lamp in which gas from the tank is burned continuously.

Double Contact.

One of the large works employing double contact is at Burnley, whose population is 97,000. The works are in many respects similar to those at Oldham except that the sewage is held up twice.

Burnley was operated originally as a chemical precipitation plant. At present seventeen septic tanks are in use, one of which is covered. During 1904 this tank and the adjoining one, which is open, received the same amount of sewage, and when at the end of twelve months the tanks were emptied, each held practically the same amount of sludge. The chemical analyses of the effluents from the two tanks were also identical, showing therefore no advantage for the covered tank. Sewage from tanks and grit chambers is pressed and sold to farmers at 10d. per ton. The combined area of primary and secondary beds is about 60 acres. The site was originally used for a sewage farm, and its success may be imagined from the fact that the soil is so heavy that the floors and walls of the beds are made of it, no concrete being used at all.

An interesting feature at this plant, at the present time, is the work of rescreening the material in the beds, which was mainly cinders from boilers. This material has so disintegrated that a number of beds had, before cleaning, less than one-fourth of the original capacity, and one bed was almost a solid mass. All material is now screened and washed before it is put into the beds. Secondary beds are filled with fine material. The standard is the same as at Oldham.

The works at Manchester, Oldham, and Burnley have many things in common. In all three works the filling and emptying of beds is done by hand, men being employed solely for this purpose. No doubt, much of the success of these works is due to the very careful manner in which the filling and emptying is attended to by the skilled men in charge.

Some smaller works employing double contact are operated automatically by Adams air locks and siphons, as at the experimental works at Bradford, and the works at Sutton, Guildford, and Richmond. These appliances apparently work well and give little trouble.

The works at Sutton use double contact, are the original works of Mr. Dibden, and apparently give very good results. (See Baker's book for full description.) At these works the material in the beds does not differ greatly and the depth is about 3 feet, except at Exeter, where the depth is 5 feet. At Richmond the effluent passes over a weir and in a thin sheet over an 8-foot wide channel.

Sprinklers.

Sprinklers, or streaming filters, as some call them, are coming very much to the fore. In fact, the new work for the past year seems to have been principally of these. Sprinklers are of two kinds—rotary and stationary.

The finest plant of the former class, and in fact the finest piece of construction work of all, is at Spondon, near Derby.

Derby has 125,000 inhabitants and a daily dry-weather flow of 3,000,000 imperial gallons, composed of domestic and trade wastes.

The sewage, after running through the grit chambers and open septic tanks of a depth of 10 feet, is distributed by a channel to eighteen Adams rotary sprinklers. The beds are circular, diameter 100 feet, and built above the surface of the ground. The exterior walls are of brick. The base of each bed is surrounded by an open channel connecting with the main effluent channel. Material in beds is 6 feet deep. These beds are filled with furnace clinkers, except the

top layer, which is of crushed stone about 6 inches in size and smaller.

The sprinkler is really a Barker's mill, and consists of four tubular arms connected to a vertical tubular shaft. The arms revolve in a horizontal plane. The sewage is distributed over the beds by the arms, which are perforated in such a way as to give uniform distribution, the space between the perforations being greatest near the center of the bed. It is claimed that a head of 18 inches is sufficient to operate the sprinklers properly.

The beds are expected to give good results when operated at the rate of 1,000,000 gallons per day per acre.

Great effort is made at these works thoroughly to aerate the beds by means of terra-cotta pipe with open joints laid radially through the filtering material and laying the exterior in open brickwork. These works were constructed under the direction of James McKie, M. I. C. E., after plans by the late James Mensergh, M. I. C. E., and reflect great credit upon both. The sample of the effluent in the chemist's laboratory is very clear. The works are not completed.

Another recently constructed plant on this order is at Buxton.

At Salisbury there is an interesting plant now being enlarged to take sewage of the corporation and that of some outlying districts recently added. The works at the present time take only about one-half of the daily dry-weather flow, which is 2,000,000 imperial gallons. The works are unique in several particulars, one of which is that the septic tanks are built above the surface of the ground without any earth backing. The sewage flows through a screen and then through grit chambers to a collecting tank, from which it is pumped into a channel supplying the septic tanks. From the septic tanks channels lead to automatic rotary sprinklers, three in number, and two Stoddard stationary sprinklers. Septic tanks are not covered and grass is growing on part of the scum.

Material in beds is clinkers from refuse destructor, the outside wall being laid up of larger clinkers, and the smaller material is used for filling on the inside. The floor of the beds is a flat conical surface of concrete, on which bricks are set on edge in radial rows. The distance between the rows is ½ inch to 2 inches or more and forms the underdrain for the beds. A channel connecting with the main effluent channel surrounds the base of the beds. The effluent from the beds is good, but not good enough for Mr. Bothames, the city surveyor, who has adopted a scheme of simple filtration of the effluent from the

sprinklers. These filters give a remarkably clear effluent, and the scheme has been so well thought of by the Local Government Board that in extending the new works it has required only four acres of these secondary filters instead of some twenty acres of land treatment (one acre per 1000 inhabitants, as is the rule of the Board).

The material of the secondary filters is merely screened clinkers of about $\frac{1}{4}$ inch to $\frac{1}{8}$ inch. The beds are about two feet thick and underdrained. When deposit on the beds gets thick, the bed is rested and the deposit allowed to dry, after which it is taken off. This is done about every fortnight.

The rotary sprinklers seem to work very well, according to the manager of the works. The new work is all of the rotary sprinkler type.

Birmingham has a very large sewage farm, and, as before remarked, made one of the first attempts at sewage purification. The farm contains about 1700 acres and is a narrow strip from five to six miles long. The sewage is received at Saltley, the upper end of the farm, and runs through five grit chambers, and from these through 17 sedimentation tanks which have only been cleaned once within three years. The effluent from the tanks then flows through a large covered conduit the whole length of the farm. At a number of places along the conduit the sewage is pumped by centrifugal pumps driven by portable steam-engines on to the fields. Special storm-water beds are also in use here.

The novel feature of the Birmingham plant, however, is at the lower end (at Minnworth). Here a new plant is being constructed using stationary sprinklers. There are also four rotary sprinklers, used originally for experiments.

The stationary spray-nozzle type of sprinklers are the only ones now being extended, as Mr. Watson, the engineer, is very enthusiastic over these.

The sewage after leaving the septic tanks flows through the whole length of the main channel before mentioned and then passes through Dortmund sedimentation tanks. The overflow from these tanks is 5 feet above the spray-nozzles. The beds have an area each of one acre, and are four in number, two of which are in operation and two partly constructed September, 1905. They are filled entirely with crushed granite, varying in size from $\frac{1}{4}$ inch to $2\frac{1}{2}$ inches. The depth of the beds is 5 feet.

The outside walls of the beds are laid up of large granite stones. The floor of the bed is of concrete; on this is laid terra-cotta channel

pipe of special design, 12 inches in diameter, and above this is the crushed stone.

On the top of the beds are laid the cast-iron feed pipes in gridiron fashion. In the top of the pipes are inserted spray-nozzles about ten feet apart. The position of the nozzles on adjoining paralleled pipes is alternated, thus attaining a fairly uniform distribution. An attendant, with hip boots, constantly watches the operation of the nozzles, which are naturally easily clogged. The appearance of the beds with its multitude of miniature fountains is an interesting sight. There is little odor. The capacity is about 750,000 gallons per acre.

The effluent from these filters is again passed through a sedimentation tank similar to a Dortmund tank to further take out the suspended matter. This tank is emptied once in about twenty-four hours and the suspended matter thrown on land. The sludge from the screen chambers and septic tanks is also pumped on land. Everything at Birmingham has the appearance of being done in the best manner.

Birmingham has a daily dry-weather flow of 25,000,000 gallons. It is a great manufacturing city, and the sewage contains many trade wastes, yet the scheme of treatment now being adopted to supplant the farm seems to be successful. It is worth while to watch closely what is being done here.

At the Frizinghall works at Bradford several experimental sprinklers are in operation. One of these has for its material fine coal about the size of peas, and it is the opinion of Mr. Garfield and of Prof. Bostock Hill that coal is a singularly effective material for streaming filters. This is perhaps worth remembering in Pennsylvania. Another point at these experimental bacterial works is that the sewage treated has all first been precipitated by sulphuric acid. Mr. Garfield claims that instead of this being detrimental, it is beneficial and promotes bacterial activity.

German Works.

In Germany the writer visited only the city of Berlin and the immediate vicinity, meeting Dr. Thumm of the Royal Experiment and Testing Laboratories for water-supply and sewage purification. The work is carried on by the Prussian Government.

At the sewage pumping station at Charlottenburg, which is in charge of Dr. Zahn, the sewage is pumped on sewage farms, of which there are a number in Berlin. At this station a few small experimental sprinklers of the English type are also in operation.

The Germans have not thus far taken very kindly to the bacterial treatment, and the cause is not hard to find, as the soil in northern Prussia at least is of a very sandy nature. The disposal of sewage by farming or broad irrigation is therefore not troublesome or difficult.

There are, however, a number of chemical precipitation plants in operation, and a typical one at Ober-Schoenweide is interesting. The plant was designed by Rothe & Co. of Berlin. The method of operation is as follows: the sewage is collected in a well where it is screened; from the well the sewage is pumped into a channel, rectangular in section; this channel is at the surface of the ground and in it the sewage is mixed mechanically with a mixture of ground coal and water, to which sulphuric acid also is added. The sewage then flows into sedimentation tanks somewhat similar to a Dortmund tank. The tank has a dome cover from which the air is partly exhausted. The sludge is pumped from the bottom of the tank and forced into presses. The clarified water flows into another mixing channel, where it may be further disinfected. This is not done at the Ober-Schoenweide, the tank effluent flowing directly into the Spree.

The pressed sludge is burned in an ordinary producer gas plant and the gas generated is used to run the gas-engine which furnishes the power for operating the works. Sixty H.P. is generated, while ordinarily 30 H.P. is all the power required. The flow is 2500 cubic meters in twenty-four hours. This plant has been in operation for five years and is now being enlarged to twice its present capacity. It stands in the center of a block on two sides of which have been erected apartment houses since the plant was built, which is conclusive proof that it is not a nuisance.

The works at Guildford, England, have an experimental plant for the disinfection of the effluent. The scheme is to mix automatically with the effluent a solution termed "oxychloride" in proportions of 6 to 2000. This is done by a system of floats which regulate the discharge of the oxychloride in the proportions named to the effluent from secondary contact beds, passing over a triangular weir.

Oxychloride is made from a salt solution by passing through it a current of electricity of 4½ volts and 1250 amperes. The formula given by Mr. Fieldhouse, the bacteriologist in charge, is NaOCl. The works at Guildford came under the Thames Conservancy Board, and, according to Mr. Fieldhouse, the Board decided that the B. coli must be reduced to one per cubic centimeter. The effluent now contains 200,000 per cubic centimeter. Mr. Fieldhouse claims that this is

accomplished, and further, as at Bradford, this solution is supposed to aid bacterial action in the beds. Dr. Rideal read a paper on this subject before the Royal Sanitary Institute (vol. xxvi, No. 7, 1905).

The conditions in eastern Pennsylvania are not very different from those in England, and in many cases English works can be quite closely followed with success. It would no doubt be advisable, before deciding on plans for a city of any size, whose sewage contained trade wastes, to first put down an experimental plant.

Too much has been claimed for the septic tank. While it will perform certain valuable work, yet cleaning is necessary, and the tank should be designed so that this can be readily done.

Operation of works in England shows clearly the value of efficient and intelligent supervision.

Another great factor in the successful operation of works in England is that effluents are systematically inspected by the Local Government Boards. The works manager never knows when the inspector may be around, but if the effluent happens to not come up to the standard, the manager will not be long in finding out when the inspector was at the works.

State inspection by the Board of Health will come here too, as it should, and not until it does will we get uniformly good results.

DISCUSSION.

P. J. A. Maignen.—When I was living in London some twenty odd years ago, my attention was drawn to a very successful sewage disposal plant at Edmonton, designed and supervised by Mr. E. Eedes Eachus, C. E. Chloride of magnesium was used; the treated water was allowed to settle in tanks; water-cress was grown in the effluent, and the sludge was allowed to dry in large concrete tanks.

In London about the same time sulphuric acid and manganate of soda were used as precipitants. The sewage was allowed to settle and the sediment carried out to sea in barges. Later on in the 90's lime and iron were used. What has become of all these systems? Are they still in use? If not, why not?

The bacterial side of sewage purification is full of interest. If you place a bottle of fresh sewage on a shelf in a room and examine it daily, you may find at first 200,000 bacteria per cubic centimeter. Twenty-four hours afterward the number will have grown to one million; forty-eight hours after to two millions, two days later to five millions. Then after about a week the number will begin to grow less and less every day, until after a month or so the number of bacteria present may fall under the original count. In other words, if sewage fluid is left to itself without addition of fresh food or renewal of water, the time comes when the bacteria cease to grow and the greater number perish by a kind of autointoxication—the environment has become poisonous to them, or it may be that all

the suspended organic matter having been reduced they find no more appropriate food and die of starvation or old age.

The period of time best suited for the full development of bacterial life in sewage is a moot question, and much division of opinion exists among authors as to whether the so-called septic tanks should be made for eight, twelve, or twenty-four hours' flow or longer.

I fail to see the difference between so-called septic tanks and cesspools, or sewage sedimentation tanks. The same phenomenon goes on in all cases, the dead organic matter is resolved into primary elements—earth, water, and gas—by the instrumentality of the micro-organisms.

We would find it a very interesting study to determine the means of promoting or checking the fermentation process in order to obtain the best results with the varying quality of the raw product and the degree of purification required.

We have heard that the chemical treatment of sewage is prevalent in England, and that it has been carried on for many years. Are there any objections to this treatment, and if so, what are they?

It has been said that chemicals do not act well on stale sewage. If chemicals are applied to fresh sewage, there is a loss of chemicals owing to their combination with the suspended matters, so that an excess is required to act upon the dissolved organic matter.

Another objection has been raised against chemical treatment, namely, the increase in the quantity of sludge produced. This increase is practically equivalent to the amount of chemical added.

It seems well established now that the septic or fermentative action reduces the quantity of solids and therefore of sludge. This is a factor which is certainly worthy of serious consideration.

I have some recollection of a system being used in Germany and in this country about twenty years ago, known as the Podiville system, or Augsburg process, wherein the sewage was treated with sulphuric acid and boiled in tubular boilers. This I understand was a failure in this country owing to the diluted condition of American sewage and the excessive cost of sulphuric acid.

In my opinion the filtration of sewage is a mistake. The accumulation of organic mud in solid filtering materials is a factor which becomes after a time expensive and offensive. I believe that in future greater attention will be paid to improved systems of sedimentation and irrigation.

The few sewage sand filters which I have visited in this country appeared to me to be failures. The effluent was not satisfactory, or the quantity filtered was insufficient.

That filtration can purify almost any kind of liquid may be granted. For instance, it is related that an experiment was made years ago with a vertical tube 50 feet long filled with sand. Salt water was poured in at the top, and the water coming out at the bottom at first was quite sweet—the salt had been extracted by coming in contact with the dry sand. But this property of removing salt did not last long. After a few minutes it was exhausted, and as the filtering operation was continued the water came out of the filter as salty as it went in. Of course, this process of extracting salt could never be rendered practicable. The sand could not be renewed often enough to turn any appreciable quantity of sea-water into fresh water.

The sewage filters at the beginning may give good results but they do not maintain their power. In some cases the effluent of artificial sand filters when left to itself turns black and foul. In other cases the fats and oils of the sewage transform the sand into impermeable putty.

The art of filtration does not consist exclusively in passing water through filters or stopping the mud; the most difficult operation is that of cleaning the filters when they are dirty, and disposing of the accumulated mud in an economical manner.

I have been interested in filtration for twenty-eight years and have seen many failures. When suspended organic matter has accumulated in filtering materials, it is not easy to separate the two, particularly in the case of sewage filtration. The cleaning operation is necessarily expensive and often offensive.

The irrigation system as used in Paris, Berlin, and many other places will give good results if there is enough land to allow plenty of rest between floodings so that the ground has time to recover its porosity, but it is difficult to find the areas necessary or the gravelly soil required for the purpose. Moreover, in winter the ice seriously interferes with the process. In artificial filtration you collect a large quantity of offensive matter in a comparatively small body of filtering materials and the combination of the two soon becomes a nuisance.

William Easby, Jr.—Replying to Mr. Maignen in regard to chemical precipitation—of course, the principal objection is the cost. A further objection is that the organic matter in solution is not largely removed, and the effluent from such a tank will undergo a subsequent putrefaction. If the chemically precipitated sewage is to be applied either to contact beds or to filter beds, the chemical treatment which it has received will interfere with the bacterial life which is necessary for purification. In other words, the chemical treatment acts antiseptically and postpones the time when the organic matter will be broken down and mineralized.

M. R. Pugh.—The process of intermittent sand filtration—the Massachusetts method, as it is frequently called—gives effluents that are far superior to any resulting from chemical precipitation, both bacteriologically and chemically.

Henry Hess.—At a sewage farm in Berlin which I visited it is the regular practice for the workingmen to drink the effluent, and I was told that typhoid diseases are unknown among them.

Charles F. Mebus.—At most of the works that I visited I noticed some odor, but it was not objectionable. The time of the year was September, but the weather was not warm.

The analyses made of the sewage in the different stages of purification show a marked improvement in each successive stage.

At only one place did I learn the number of bacteria found in the effluent of the second contact bed, and that was at Guildford, where it was said to be 200,000 Bacillus coli per cubic centimeter. The local Government Boards do not, to my knowledge, prescribe any bacterial standard.

PAPER NO. 1017.

HIGH-SPEED ELECTRIC RAILROADS.

HENRY G. MORRIS.

Read November 18, 1905.

THE spirit of American enterprise is not likely to be content with the fact that Germany holds the world's record for high-speed transportation. All are doubtless familiar with the results of the electric speed tests made in 1902 and 1903 on the government railroad between Zossen and Marienfelde. As the data furnished by these tests suggested possibilities which finally resulted in the design of a radically new system to overcome the adverse conditions presented, it may be well to review some of the more important facts developed in this extraordinary series of German experiments.

Preceding this, your attention will be invited to some of the conditions governing steam and electric railway practice in this country, with present speed limitations. The advance made by the Germans and the necessity for still further radical changes before speeds in excess of 100 miles per hour can become commercially practicable will be presented as briefly as possible. In this connection will be outlined the essential features of a high-speed electric railway system designed to make a speed of 120 miles per hour feasible. The invention of this system has developed a theory of transportation which may be stated thus: "In any vehicle the body to be transported should be concentrated over the fewest possible supporting wheels. These wheels should be placed tandem instead of parallel with each other." It will be evident that the subject suggested is an extremely broad one, so that in the scope of a single paper elaborate technical detail cannot be presented.

STEAM RAILWAY CONDITIONS.

Last year the operation of railroads in the United States killed 4,000 and injured 55,000 people. A population equal to that of the entire city of Harrisburg, Pa., killed and injured in a single year! This statement, it must be admitted, does not sound encouraging for increased speed under existing conditions, but rather presents an appeal for safety. It asks that not only those who travel, but those who build

and operate railroads, should "Stop, look, and listen!" Now, the American public may not be speed crazy, but it desires to travel as rapidly as possible even with some element of risk. From dictates of both humanity and economy, however, this public demand should not be catered to except with an increased rather than diminished factor of safety.

Railroad accidents, as we know, consist chiefly of collisions and derailments. According to a bulletin of the Interstate Commerce Commission, there were in this country, during the first quarter of the present year, 1,787 collisions and 1,321 derailments—an average of about 12,000 accidents per annum.

It will be observed that collisions form the larger percentage of these accidents. Where passenger trains were involved with freight, the occasion was ordinarily due to wrong or mistaken signals, misplaced switches, shunting of freight at the wrong time, and the breaking apart or the buckling of freight trains due to inadequate or improper distribution of air-brakes. The freight train, either in direct collision or indirectly from misplaced switches at freight sidings, is such a prolific source of disaster to passenger trains that upon lines where enormous passenger business is involved the question of segregating passenger traffic and adopting an independent road-bed is worthy of serious consideration. With a proper block signal system this would leave grade-crossing accidents and derailments the principal elements of danger. The former should, of course, be abolished in any high-speed system, and having eliminated freight switches, causes of accidents would be confined largely to boiler explosions, spreading of rails, breaking of wheels or axles, and centrifugal effects at curves improperly elevated for high speed. On tracks carrying mixed traffic the elevation of the outer rail on curves is necessarily a compromise between high-speed passenger requirements and the slower freight train speed, with the result suited to neither. These conditions should be considered in a high-speed system, and where tracks for general traffic *must* still be used, the high-speed passenger car should also operate safely and independently over existing switches, whether misplaced or not.

Discomfort in steam travel is largely due to pounding of rail joints, lateral oscillation of the car owing to the impossibility of maintaining two parallel rails in perfectly uniform surface, and of course the usual annoyance from dust, smoke, noise, and cinders. These are all preventable conditions, partly remedied by present forms of electric service.

The steam locomotive has never presented perfect conditions of traction. The ideal locomotive is one which concentrates over its drivers not only its own weight but the entire weight to be transported. The locomotive of the four-car train known as the Chicago Special weighs with tender about 185 tons. The four cars aggregate 120 tons. In other words, over 50 per cent. of the available power is consumed in propelling the locomotive itself, leaving about 45 per cent. to draw the car at an average speed of sixty miles per hour. The 2,500 H.P. of the locomotive is fully taxed, requiring about 250 actual H.P. per car, or 600 H. P. per car including locomotive transportation. This is not an economical arrangement. Aside from this, the locomotive fire-box, in itself, is extravagant in coal consumption as compared with the fine economies of the modern power station. Also the locomotive, whether steam or electric, does not allow proper flexibility of car or train service, particularly where frequent runs are required. Upon a given schedule a locomotive may draw its full complement of passenger coaches half filled or half its cars. In either case we have the familiar example of a man being employed to do a boy's work. Further, the steam locomotive is not adapted for extremely high speeds by the very intricacy of its design. With its complicated reciprocating valve gear, large number of moving parts, and high boiler pressure at excessive speeds it presents an element not only of extravagance but of positive danger when pressed beyond proper limitations. Its center of gravity is also high above the rails, which detracts from its safe speed possibilities. These criticisms are made with due regard for the great work accomplished for civilization during the past three-quarters of a century by the steam locomotive. We are considering it here only in its relations to the high-speed problems of the present and future, particularly in territory where the population is large enough to warrant frequent service.

Electric Traction.

It is unnecessary to go extensively into the development and present status of electric railways. Less than twenty years ago the electric car was a toy propelled by a spark—the plaything of a few men of cultivated imagination. Ten years ago it was generally conceded that it had come to emancipate the horse from street-car travel. It was not seriously considered as a competitor in suburban, much less interurban, traffic. To-day electric locomotives drawing several Pullman coaches outclass in speed tests the Empire State Express, and single electric cars have been propelled at a speed that, in passing,

would make the Chicago Special appear flying backward at the rate of a mile a minute. There is no question about the ability to propel electric cars at any desired speed. The problem is to make high speed feasible.

The practical application of high-voltage alternating currents to long-distance transmission of power is an important factor in bringing electricity into the field of express passenger traffic. The advantage of a centralized, economic power station with a skilled engineer with one coal bin to watch, as compared with a large number of scattered locomotive units with separate engineers, firemen, and fire-boxes, is apparent. The further introduction of single-phase alternating current transmission and single-phase motors eliminating expensive substations and attendants promises much for the immediate future. Many engineers also maintain that the great advantage of electric railroads as compared with steam consists, with the aid of these long-distance transmission lines, not only in using a centralized power plant, but in concentrating each car over its own motors—in establishing the motor-car unit with its wonderful possibilities of flexible car and train service under the multiple unit-control system.

The substitution of electric power on important steam lines is so recent that little data for a comparison of economies is available. We have the following, however, in the case of the Manhattan Elevated Railway:

	Steam. 1896.	Electric. 1904.
Operating ratio—per cent.,	58.1	41.2
Passengers carried,	185,138,000	286,634,000
Car mileage,	43,241,000	61,743,000
Receipts, car mile (cents),	21.6	22.95
Total operating expenses (cents),	13.2	9.5
" " " per passenger,	2.92	2.04

From this statement it will be observed that the operating expenses per car mile and per passenger for electricity were only two-thirds of the cost by steam. The receipts per car mile are not materially different. The gross receipts increased sixty per cent., part of which was doubtless ordinary annual growth. The economy of electric operation, however, is significant. The introduction of electricity for passenger travel on the New York Central and Hudson River Railroad, the West Shore Railroad, the New York, New Haven and Hartford Railroad, the Long Island Railroad, and other steam lines indicates a recognition of the demand of the hour for better transportation. In the middle

west long-distance electric railroading with its dining-car and sleeping-car service is much more highly developed than in the east, where it seems likely to result in the electrical equipment of existing steam roads connecting large centers of population, rather than in the building of extensive independent rival systems. The present intervening highway lines, though often of considerable length, are generally but little more than street railways catering principally to local business, and do not come within the class of traffic under consideration.

German Tests.

The high-speed railway tests conducted in Germany give the first material data upon which to base a substantial hope of two miles a minute passenger service. The Germans propelled electric cars at a speed of 135 miles per hour. Two cars were furnished respectively by the two leading electric manufacturing companies of Berlin. They each weighed about 100 tons equipped—six-wheel double trucks were used with three-phase alternating current motors, two on each truck. The armatures were keyed directly to the axles rotating within pole pieces suspended on the truck frame; they operated at 8,000 to 10,000 volts, the current being collected from three overhead wires placed in a vertical plane against which six trolley poles carrying bows pressed laterally. The car-body had no extraordinary features except a detachable nose on the front vestibule to reduce head-end air resistance.

The steam road-bed used in the preliminary tests was unsatisfactory. The T rails (67 pounds per yard) and ballast were inadequate, resulting in vibration and lateral oscillation of the car-body, at speeds in excess of 80 miles per hour, to a degree both uncomfortable and unsafe. Later, heavier 82.5 pound T rails, with ties spaced 27 inches between centers, and better ballast were substituted with more satisfactory results. At speeds between 70 and 90 miles per hour, however, the oscillation of the car-body was still considerable. Above speeds of 90 miles per hour the passengers were surprised to find less swaying and discomfort. The explanation, of course, is that a car propelled at speeds of over 100 miles per hour is quite as much a projectile as a vehicle. It tends to move in a straight line with respect to a horizontal as well as vertical plane. It partly overcomes the forces of gravitation and merely touches the high points in the track. When a rail is higher than that immediately opposite, the wheels on the high side alone are in contact, the car-body and truck being level, thus incurring great risk

of derailment. This feature was so fully recognized by the Germans that heavy guard rails were placed inside and extending 2½ inches above either supporting rail. They served to keep all the wheels *over* the bearing rails, but not necessarily in contact with them, so that conditions of traction were often far from satisfactory. This will be readily appreciated when we recall that the 95 tons weight of the car was distributed upon twelve wheels. Curves sharper than one-mile radius were found to require reduction of tangent speed below 120 miles per hour, flange friction and danger of derailment being both conspicuous.

The reading of block signals at a speed of two miles per minute was shown in the German test to be impossible, even in clear weather, and the plan of automatic electric signal lights, flashed in the vestibule of the car itself, has been suggested as the satisfactory solution of this problem. It is unnecessary to state that a reliable block system is a prime essential of any high-speed railway.

The heavier 103-ton car operating on this 15-mile run between Zossen and Marienfelde required at a speed of 120 miles per hour no less than 1,300 H.P. At this speed the friction of 12 journal boxes, 12 points of rolling contact, and the head-end air resistance become formidable, and excessive power is required, especially under the unsatisfactory conditions of traction previously mentioned, where sufficient weight is not uniformly maintained on the driving or power wheels. Of the 1,300 H.P. at the above speed about 500 H.P. (or only one-half the amount calculated from Smeaton's formula) was required in overcoming head-end air resistance, and the remainder in journal flange and rolling contact friction and lateral motion—in train resistance. Heavy populations doubtless justify two miles a minute service, even with this heavy power consumption, and this feature is not regarded as a serious factor in the equipment of the proposed 157-mile line between Berlin and Hamburg to operate at this speed. Nevertheless a material reduction of this power consumption will in many instances be found necessary to render a given enterprise financially feasible.

Summary of High-speed Problems.

Briefly reviewing the problems presented in a 120-mile per hour service before proceeding to discuss a detailed solution, we have the following conditions:

1. The demand for an infallible signal system.
2. The segregation, if possible, of high-speed passenger from freight

and local passenger traffic. Where existing tracks must be used, the passenger cars should operate independently of the ordinary switches controlling freight and other traffic.

3. Danger from derailment on curves and from spreading of rails must be eliminated.

4. The vestibules of the cars must be built to minimize air resistance and to withstand the greatest possible impact in event of collision, adapted, at the same time, for flexible car or train service—for use as a single-car unit, or embodied in any part of a train.

5. The supporting rail should, preferably, be constructed so as to eliminate pounding of joints. The rail head should afford a continuous bearing surface, with proper provision, at the same time, for temperature variations.

6. Lateral oscillation of the car should be minimized.

7. Economy of producing power by water or steam generating plants, involving in either case the turbine wheel. The principle of direct rotary motion rather than reciprocating movements should apply to generating as well as using power for driving cars. Also sufficient high-voltage single-phase transmission lines, eliminating rotary converter substations and attendants.

8. A satisfactory method of collecting electric current from an overhead wire with catenary suspension, or from an insulated feed rail or other means.

9. Traction and speed should not be secured by using a heavily built car-body, but by concentrating the weight of a light, rigid, and durable body, and the passengers, upon the fewest possible driving or motor-wheels, with power applied as directly as possible.

10. The journals and bearings should be designed to reduce friction and the power required to overcome inertia and to accelerate rapidly.

11. The flange friction against the ribbon of outer rails, particularly on curves, should be eliminated.

12. Grade crossings with streets, highways, or other railways must be avoided.

13. Tangents should be maintained, even at enormous expense, in determining alignment. Curves of less than one mile radius should not be employed on main lines; otherwise speed must be reduced below 120 miles per hour.

14. The system of braking should be absolutely reliable and effective.

15. The system as a whole should be adapted to existing standard railroad road-beds and rolling stock, in order to become commercially feasible in the broadest possible sense.

The Bicycle Principle.

Boys who have been so fortunate as to possess gyroscopic tops have gazed in astonishment at the steadily revolving disc in a vertical plane with its horizontal axis supported at only one end several inches distant. The bicycle gives less cause for wonder, with its central tandem support with absolute steadiness of motion and lack of tendency to sway or oscillate at high speeds. More than any other vehicle the bicycle also meets the conditions of the ideal locomotive by concentrating the weight to be carried upon the fewest possible driving-wheels or points of rolling contact. It derives more traction and speed with a given power than any other form of vehicle. It involves a single central line of tandem support, which is the correct principle to follow in propelling a vehicle at high speed along a tangent. And, as we have already seen, a vehicle traveling at enormously high speed tends to project itself along a tangent in both a vertical and a horizontal plane. Hence the double advantage of the bicycle principle in the matter of both alignment and track surface, for the fewer the points of rolling contact with the rail and the greater weight upon each, the firmer and more uniform the contact and the better the traction, speed, and power economies. While all high-speed railroads should be located in harmony with the familiar geometric axiom that a straight line is the shortest path between two points, we know that curves are too frequently a necessary evil, and in this connection it will be conceded that the bicycle turns a corner or rounds a curve more gracefully and with less friction and greater speed and safety than any other form of vehicle.

These are a few of the impelling reasons which led to the adoption of the bicycle or mono-rail principle as the correct solution of the high-speed transportation problem, and before outlining its practicable application to standard railroad conditions a brief review of the work already attempted in the mono railway field may be in order.

The Mono Railway.

Many will recall at the Philadelphia Centennial Exposition of 1876 a short A-shaped elevated trestle with a supporting rail placed at the apex and guide rails below on either side. A car and locomotive straddled the structure, being divided into two parts, with the car-seats on either side, facing away from the track. A line of this kind has been operated by steam for a number of years between Listowel and Bally-

bunion in Ireland. It has shown satisfactory economy and has been singularly free from accidents. A speed of only about thirty miles per hour is maintained, so that no high-speed data is available.

A few years ago a short experimental line was similarly constructed near Brussels, with the elevated structure about four feet high and electrically equipped. A car weighing 60 tons, with four supporting wheels and a large number of balance wheels carried on extended arms below on either side, was used. It had eight motors—one on either side of each supporting wheel. Air-brakes were used. A speed of 90 miles per hour was attained and the experiment considered sufficiently successful to warrant the construction of a line for commercial purposes. With this view parliamentary rights have been secured for a line thirty-seven and one-half miles in length between Liverpool and Manchester. It is proposed to make the run in twenty minutes.

A line is now in operation in Germany at Elberfeld for local traffic in which a single rail is carried under the arch of inverted ∩-shaped steel supports, and a small light car suspended from overhead wheels travels on this rail. It is unique and an attraction to visitors, but its cost of $200,000 per mile is excessive considering the character of the car and service.

In this country one or two experiments with light cars have been made with a single supporting rail placed upon short ties and overhead guide rails supported by poles and brackets or by steel columns either side of the track at frequent intervals with cross-girders. Between two overhead guide rails wheels travel, carried by a short arm extending from the top of the car. These cars were applicable more particularly to pleasure riding and have never been adapted to commercial railroading.

The Motor-cycle Railway.

The single-rail systems just referred to all require special elevated or overhead structures, in order to permit of operation. The cars are not adapted to, and cannot operate interchangeably over, existing railways. The problem of high-speed transportation is not approached from the viewpoint of the standard steam railway manager, controlling millions invested in existing road-beds and rolling stock. It is apparent, however, at this time that in order for any system to have a general application and become commercially as well as physically feasible, this important feature should not be overlooked. The transition from steam to electricity should take place with the use, to the largest possible degree, of existing assets. Road-beds must, in many

instances, remain available for steam as well as for electric railway service.

A system called "the Motor-cycle Railway" has been designed to accomplish this, by placing upon the ties of standard road-beds a central supporting rail, leaving steam locomotives free to handle freight or other traffic over the two existing rails, which also afford support for the balance-wheels of the motor-cycle trucks.

The equipment provides a car carried on two trucks, the weight of the car-body being concentrated on two motor wheels placed tandem in each truck on a central rail. Two balance-wheels on either side of a truck travel on the outer rails spiked to the ties on either side of the central rail. The car-body has a steel frame with steel sills extending under the vestibule at either end of the car in the form of a parabola with comparatively pointed apex, further reinforced by diagonal steel bracing forming a trussed steel arch of enormous resistance. The double doors in front of the vestibule admit, when opened outward and connected with doors of a similar car, of vestibuling the train.

Owing to the weight of the motor wheels (about five tons each) the car-body may be comparatively light, being concentrated on only four of these wheels with their deep, heavy, double flanges. It will be practically impossible to lift these wheels sufficiently high to admit of derailment, owing to the fact that they always carry a large percentage of the weight of the equipped car. Balance-wheels having no flanges eliminate the customary grinding and friction against the ribbon of the outer rail on curves. With proper transition curves and elevation of outer rail a motor-cycle truck will round a curve with almost as much ease and absence of friction as a bicycle does in turning a corner as compared with a four-wheeled vehicle. These balance-wheels will travel readily over ordinary frogs and switches, whether closed or open.

In operation it will be apparent that, like the bicycle, the greater the speed, the less will be the tendency of the motor-cycle car to oscillate from side to side and the more comfortable the riding. The springs over the journals of the balance-wheels are comparatively weak and are designed not to transmit jolts or swaying to the body of the car in event of ordinary inequalities in the surface of the outer rails. A reasonably perfect surface on the single central supporting rail is alone essential in securing freedom from vibration and oscillation, except on curves where the outer guide rails must be maintained in good surface in case the car or train rounds the same curve at a con-

siderably greater or less speed than the outer rail is elevated for, in which case there is pressure through the heavier springs of the truck frame and balance-wheels upon the top, but never against the side of the rail.

A central supporting rail has been designed to afford a continuous bearing surface for the motor wheels, thus eliminating pounding and vibration at rail-joints. The rail is constructed in two half-sections, forming a triangular structure with one half-section forming a base for the entire rail. The half-sections bolted together break joints with each other. The bolts and nut locks, owing to the sides of the rail being beveled, cannot turn, thus solving a troublesome feature of track maintenance. It requires no angle plates. The space inside the rail as a conduit for carrying electric wires and cables is an incidental feature which may prove of practical value.

The Motor-cycle.

The two motor wheels placed tandem in each truck carry an armature keyed to each axle which does not revolve. The fields or pole-pieces are carried within the rim of the wheel and rotate around the armature similar to a rotating field generator. The wheel may also be constructed with pole-pieces fixed on the axle within a revolving armature. The electric wires or leads from the platform controller are inserted through a core in the axle, and lead to revolving brushes, counterpoised to neutralize centrifugal effects; these brushes distribute current to fields, commutator, and armature. The commutator brushes revolve preferably upon the ordinary horizontal cylindrical commutator surfaces. Either direct or alternating currents, or both direct and single-phase alternating, in the same motor-cycle, may be used. All electric parts of the motor wheel are protected by a cover, partly removable, with proper apertures for air cooling. The ventilation of the wheel embodies the principle of the choral top, receiving air at the vacuum created at the axis and discharging it by centrifugal force near the rim, passing meanwhile continually over brushes and commutator. The entire motor wheel and axle can be readily dropped from the truck frame at repair pits. The wheel has a removable tire of steel with heavy double flanges at least two inches deep. Automatic lubrication is provided for bearings. These are roller bearings with rollers two inches in diameter and ten in length—a total of twenty inches lineal contact in the two bearings of each wheel. As the weight is always distributed on at least three sets of rollers, this

means a total of sixty inches of contact surface in each wheel—which with the large two-inch rollers and comparative absence of end-thrust makes crushing impossible.

Additional Safety Features.

The vestibules, as previously stated, are designed in the form of a parabola, for the double purpose of minimizing air resistance and protecting the car-body in the event of collision. These vestibules are further equipped with the multiple unit control, each car carrying its own motor wheels operated from the head of the train. Trailers without motors may, of course, be used, or trains made up only partially of motor cars. An additional factor of safety is introduced in the form of a pilot, which in the event of collision with the pilot of another car is depressed and acts as a brake in contact with the center rail.

A system designed for speeds in excess of 100 miles per hour necessarily contemplates the elimination of grade crossings with streets, highways, and other railways, and the most reliable automatic signal system, further checked by human operators. The signal light should be flashed not only in the signal towers, but in the car itself, visible to both engineer and conductor. The check signal in the car may be a similar light or electric bell.

Both air and electric brakes may be used, and owing to the absence of gears in the motor equipment, current in the motor wheels, particularly where alternating current is used, may be reversed for emergency stops without undue heating or injury.

General Remarks.

As previously stated, it is the opinion of many competent experts that the advantages of electric transportation consist not only in concentrating the generating power plant for an entire system at one point, but in concentrating the weight of each car over the driving-wheels that propel it, instead of at the head of a train, trailing a dead load behind it. The motor-cycle system not only concentrates the weight of each car over its four driving-wheels, but makes these wheels themselves the motors and places them in direct alignment on a single rail. This is apparently reducing the problem of traction to its simplest and most direct form. It renders possible enormously high speeds with economy, comfort, and safety, and expands the possibilities of electric transportation to an unlimited field.

It is proposed during the coming year to fully demonstrate the

mechanical and electrical feasibility of this system. With this end in view a leading electric manufacturing company has offered to co-operate in constructing four motor wheels for a double truck equipment. These motor cycles are rated at 250 H.P. each at 650 revolutions—a total of 1,000 H.P. per car of 60 feet length.

It is not presumed, however, that all of this power will be required either in accelerating or at maximum speed. The 103-ton German car, it will be remembered, required 1,300 H.P. with 12 supporting wheels at 120 miles per hour. At this same speed the motor-cycle car with half the weight and one-third the number of supporting wheels or points of rolling contact should require, with its parabola vestibule, not more than 400 H.P. for air resistance and not more than 300 H.P. for train resistance—a total of 700 H.P. The use of the entire 1,000 H.P. motors at their maximum capacity it is believed will develop a maximum car speed of 140 miles per hour, should track conditions be found to warrant it.

The car-body should be made rigid, durable, and light. Steel should be used at least for the frame, and a steel sill should extend unbroken under the parabola vestibule. In this connection the diagonal steel bracing makes an arch not only of great resistance, but of considerable resiliency. This arch should not be weakened by inserting steps. No fixed steps will be required, as station platforms should be level with car platforms. While it is not claimed that a collision at two miles per minute would be a harmless affair, the danger can be greatly minimized when collisions at any speed do occur by proper car construction. The lighter car-body means less momentum. The steel arch vestibule means an element of safety many times greater than the Pullman vestibule, the life-saving qualities of which are well known. With a double-check infallible signal system these extraordinary provisions in vestibule construction may seem inconsistent and superfluous. In railroading, however, experience shows that we must plan to make accidents absolutely impossible, and then make every provision for them.

The successful demonstration of such a system as outlined will necessarily mark an important advance in transportation. The operation of the first steam locomotive and train at 20 miles per hour began a new era by doubling the existing stage-coach speed. We are reminded of the conservative spirit of our ancestors, who opposed any such reckless breakneck performance as an average speed of 20 miles per hour—rivaling the best race-horse. "Ten miles an hour was fast enough for anybody." Today, with all our boasted spirit of twentieth

century progress, when it is proposed to double the present train speed of 60 miles per hour and bring humanity just that much closer together, we hear in a few quarters the same timid breath of conservatism. "A mile a minute is fast enough for any one." Under existing steam railroad conditions we must admit that this is true. Examine the top-heavy locomotive with its complicated mechanism and shallow wheel flanges as you leave it in the train-shed at the end of a mile a minute run; recall the curves, frogs, and switches it has lurched, slid, and banged over, and you will marvel that it remained on the track.

It must be admitted that if we cannot have both speed and safety the latter should have first consideration. But it *is* possible to have both increased speed and increased safety, and the American public will appreciate both. Two years ago the manager of an important trunk line stated that 70 miles an hour was the maximum limit of feasible train speed. To-day he is running a train at enormous expense, with steam locomotives not adapted for the work, at approximately 90 miles per hour for short bursts of speed, and an average of 60 miles an hour. In point of fact there is no limit to speed possibilities or speed requirements, and none will be recognized by this or succeeding generations. Once establish a system that insures a speed of 120 miles an hour with safety, comfort, and economy, and present methods of transportation will be just about as popular as the stage-coach was with our grandfathers after a better method of traveling twice as fast was presented.

A glance at the motor wheel itself suggests possibilities of unlimited speed. It will be apparent that the question of speed is simply the matter of the size of the wheel. A wheel five feet in diameter at 650 revolutions per minute means 120 miles per hour. Wheels six feet in diameter at 700 revolutions give power for a speed of 150 miles per hour. Compare the simplicity of the motor wheel, with its four rotating pole-pieces and fixed armature, with a complicated steam locomotive, or even a gear-transmission electric motor, and it will help inspire confidence in the speed possibilities of the future.

The questions naturally arise, Is there a field for such a system? Is it worth while? Will it pay? We cannot at this time go into the details of cost of construction and equipment or earning capacity in any given territory. There can be little doubt, however, that such a system, practically demonstrated, would be amply warranted for service between the principal cities of the Atlantic seaboard; between St. Louis and Chicago, and eventually New York, and between other populous

centers where the topographical conditions of the intervening country are favorable. Such interurban lines should connect with the express tracks of city subways, tunnels, and elevated lines, thus reaching business and financial centers as directly as possible. The system is also well adapted for express suburban service and interurban accommodation service, using smaller motor wheels, and should effect important social and economic changes in municipal growth. It would further tend to diffuse populations from congested city districts into the outlying and intervening country districts. It would make for better sanitary conditions and more wholesome domestic life for millions of those who toil in cities, and develop a race of country-bred children. Our cities of the future will doubtless comprise the usual downtown commercial and financial centers, shopping districts, lyceums and theaters, and in the outlying districts the industrial plants, but not within the city proper the homes of either the rich or the poor. Nearly all will live in the country, the former probably using automobiles and the latter flashed from office or factory to distant homes in a few minutes by electric cars or trains at frequent intervals through subways, tunnels, and tubes to depressed or elevated suburban tracks devoid of grade crossings. Travel between large cities will be so comfortable, economic, and rapid that the tendency must be to emphasize the individual characteristics of each municipality, and certain cities, following natural laws of development, will become more and more characterized as commercial, financial, educational, industrial, or political centers. In other words, the cities will specialize to a constantly increasing degree, with improved transportation, in harmony with the modern spirit of political, economic, and industrial centralization. This prophecy may be inopportune and premature in connection with the high-speed railway system just described, upon which it is proper to suspend judgment pending an analysis of the facts presented. The whole subject, however, is one which suggests tremendous possibilities for the immediate future.

DISCUSSION.

Jas. N. Vandegrift.—The cars used in the high-speed tests made in Germany have no very striking features except the method of collecting the electricity. They have six bow collectors upon each car, which press laterally against the three wires spaced vertically, collecting the three-phase alternating current.

These cars were propelled at a speed of 135 miles per hour, and have created a spirit of investigation into the possibilities of this high-speed problem. They furnish the first real data that we have upon which to base a belief that such a

speed is possible. The work of conducting these experiments was done under the auspices of the German Government, and under the charge of a body of able, public-spirited men, imbued with scientific zeal, known as the Studiengesellschaft, who gave a great deal of thought to the subject during the three or four years prior to 1903, when the final tests were made.

The six bow collectors on top of the car make a decidedly complicated mechanism for collecting the electricity, although the Germans claim that the results, after considerable adjustments, were entirely satisfactory. It is apparent, of course, that the use of ordinary trolleys is entirely inadequate for very high speeds. In this country the catenary suspension is being introduced on one of the leading steam roads now—in fact, the Long Island Railway, I believe, is adopting the catenary suspension for its lines, which are being electrically equipped. The form shown on the screen is the single catenary suspension, with the messenger cable insulated with porcelain insulators at the brackets, with rigid hangers which maintain the trolley wire throughout at an absolutely uniform distance above the rail; the sag is entirely in the catenary cable. For extremely high speeds a double catenary is used—two cables with the hangers extending down to the single trolley wire, forming a triangular suspension. In extremely northern latitudes I think that the catenary suspension will be found more desirable than the third rail. That is a matter, however, upon which judgment should perhaps be suspended.

As stated in the paper which Mr. Morris has just read, considerable difficulty and danger were experienced in the problem of derailments. The Germans went to extraordinary expense in guarding against this by using a guard rail, which is simply an ordinary tee rail with cast-iron supports placed upon each tie. The guard rail and its supports together weigh nearly the same per lineal yard as the supporting rail itself. The supporting rail is slightly inclined toward the center of the track. I presume that is for the purpose of bringing the head of the rail in contact with the tread of the wheel entirely across the rail. A peculiar feature is the beech pin used in fastening the tie plates to the ties; the pins are screwed almost entirely through the tie.

The question of reducing power consumption at enormously high speeds is an extremely important problem, and roller bearings as a means to that end have been considered. I was unable to get any data some three or four months ago when I took up seriously the question of using roller bearings for motor wheels; but about a month ago I accidentally found in Syracuse, N. Y., a car which has been in daily operation for three years, equipped with roller bearings. The car was run in off the street for me, jacked up in the car barn and the rollers taken out. They are 1½ inches in diameter and 7 inches long. There is a sleeve placed on the axle which does not extend throughout the entire 7 inches but affords a bearing only 4 inches on the inner side, next to the axle. The outer bearing is the box itself, which is case-hardened, and there the rollers are in contact with the box throughout their entire length of 7 inches. When this sleeve is pushed back in place the end of the axle protrudes and there is a key dropped down in the slot at the end of the axle which holds the sleeve and the rollers in place and takes care of any end-thrust. These roller bearings, although in use three years, showed absolutely no sign of wear, and there was no decrease in the diameter of the roller that was sufficient to be measured. I suggested at the time that while

the rollers had undoubtedly demonstrated their permanency and durability, a comparison of power consumptions would be very desirable, and I have been very glad to receive from the Professor of Electrical Engineering at Syracuse University, who was called upon to make the tests, some data respecting them.

Two cars were tested—the one with the roller bearings and the one with the ordinary bearings, both of the same type. Weston instruments were used—ammeter and voltmeter—and the cars were run by the regular motormen. The figures are significant. Car No. 70 with the roller bearings, for the run of seven miles, out to a certain point and back, consumed a total energy of 3.10 kilowatt hours. The other car, equipped with the ordinary bearings, required a little more than double that power, or 6.45 kilowatt hours. In other words, the car equipped with the roller bearings required only 45 per cent. of the power which the car with the ordinary bearings required.

I asked the motorman of the car equipped with the roller bearings how the car behaved. He replied that he did not like it—that he was bothered entirely too much with shutting off his power in order to keep down to schedule and to avoid running into the car ahead. I find on going over the chart of data that the power was actually off the car 55 per cent. of the time during the test run. The car with the ordinary bearings, however, required its power on 92 per cent. of the time. I have no doubt that motors of practically half the capacity of those used would have shown much better power economy because run at somewhere near their normal capacity, rather than have the current shut off and turned on alternately. The whole of the data, however, is interesting, as showing an actual test with roller bearings which have been in use for three years, with no expense for maintenance, and it seems to me that that gives some justification for believing that roller bearings are destined to play an important part in railroad transportation as well as in automobiles and lighter vehicles.

In the German tests they used 82½ pound rails with ties spaced 27 inches apart. This was not quite as close, nor were the ties quite as large as our standard ties, but they experienced no difficulty in rail deflection at a speed of 135 miles an hour. They showed that even with an 82½ pound rail, with the proper ballast, there was no great difficulty so far as the road-bed was concerned. They showed also that for such speeds the track curvature must not be sharper than one-mile radius.

At a speed of 120 miles per hour the retardation was at the rate of two miles per hour, per minute; so that the car was brought to a stop in a distance of about 4000 feet. The stops which they made were not abrupt enough to inconvenience the passengers. The Germans, in their report, indicated that with certain modifications in the use of a cylinder operating the piston directly against the wheels they are calculating on stopping the car in about 1700 feet or possibly 2000 feet. They were handicapped seriously, however, in getting the exact data in the acceleration of the car. Their power at the power station was restricted, so that they had to limit the maximum demands of the car. They used however 450 H.P. more during the acceleration than the normal horsepower consumed at their maximum speed. This allowed them to get up speed in a distance of about two and one-half miles. The conclusion which I have drawn from the tests as submitted is that a car can attain a speed of 120 miles

per hour in a distance of one mile, and that when running at that speed it can be stopped in a distance of about 1700 to 1800 feet.

John C. Trautwine, Jr.—Two or three years ago I was called as a witness for a party who maintained a wooden crib retaining wall along the line of the Pennsylvania Railroad. The Railroad Company contended that the crib structure was dangerous—that it might at any time collapse and fall in front of a fast train. It never gave me the least uneasiness to pass that structure in a fast train, but I always considered myself in danger when my train passed a moving freight train on an adjoining track. This danger—common to all railroads as at present constructed—would be largely obviated by a construction such as described in the paper.

Some twenty or twenty-five years ago a high-speed railroad was talked of to run between Philadelphia and New York. In that connection I remembered my visits to the so-called "one-rail" at the Centennial Exposition, and pictured to myself something like that running at a very high speed between Philadelphia and New York, but when I spoke of it to some experts I was laughed to scorn for deviating from the orthodox two-rail system. So I am particularly glad to find my early radical notions confirmed by so respectable an authority.

A few years ago I made a trip on a short railway arranged like the Centennial road mentioned. I think that it was at Mount Holly, N. J., and was called the Boynton Bicycle Railroad. In consideration of a small sum, the passenger was permitted to mount a so-called bicycle (with at least three wheels) and ride a mile or two and back again.

These miniature roads seem to have embodied much the same principles as those of the device mentioned in the paper.

Charles Hewitt.—I am not enthusiastic over the possibilities of roller bearings on railway trucks, though I am not familiar with the particular roller bearing which Mr. Vandegrift has described. In a paper which I read before this Club some two or three years ago I presented a set of readings taken continuously for three weeks in this city—a week each over three of our lines—and they showed as great a variation with the ordinary trolley cars as he found in Syracuse between the roller bearing car and the ordinary car. These tests are fully described in the Proceedings of the Club. Roller bearings have been tried on street railway cars a good many times, and, so far as I can find, street railway men are not enthusiastic over them. They would strike one casually as being the proper thing, but, as a rule, they have not been successful.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, October 7, 1905.—President Comfort in the chair. Sixty-four members and visitors present.

The Tellers announced that J. A. Hunter and Lewis F. Moody were elected to active membership and Henry L. Benner and Joseph Upton were elected to junior membership.

Mr. Chas. A. Barton read a paper on "A Description of the Elements of the Nernst Lamp, and Its Applications."

Regular Meeting, October 21, 1905.—President Comfort in the chair. Ninety-eight members and visitors present.

President Comfort announced that unbound periodicals, formerly given away to members, would now be sent to the University of Pennsylvania Library, in exchange for which the privileges of the University Library, including the borrowing of books, would be granted to the members of the Engineers' Club.

President Comfort announced that the Board of Directors had authorized the appointment of a committee to confer with the Chief of the Bureau of Building Inspection with a view to establishing a standard code of building regulations regarding buildings in reinforced concrete.

Mr. John C. Trautwine, Jr., read a paper on "The Early History of the Philadelphia Water Works."

Regular Meeting, November 4, 1905.—President Comfort in the chair. Eighty-six members and visitors present.

The President announced the following committee to confer with the Chief of the Bureau of Building Inspection: E. G. Perrot, Chairman, H. H. Quimby, C. M. Mills, R. G. Develin, and W. L. Webb.

The Secretary read a letter from the City Parks Association requesting the members of the Club to contribute toward the publication of the reports of that Association.

The Secretary also read a letter from the A. S. C. E. announcing that the Board of Direction had issued a special invitation to members of the Engineers' Club to attend any of the meetings at that Society.

Mr. E. W. Lazell read a paper on "Sand-lime Brick."

Business Meeting, November 18, 1905.—President Comfort in the chair. Ninety-three members and visitors present.

The Tellers announced that James D. Faires, Wm. Gowie, Edgar E. Seyfert, and Joseph A. Wolle were elected to active membership.

The Nominating Committee presented the following nominations for officers:

For President, ... Thos. C. McBride.
For Vice-President, ... Washington Devereux.
For Secretary, ... Walter Loring Webb.

For Treasurer,.....Geo. T. Gwilliam.
Walter F. Ballinger.
For Directors,.....F. E. Dodge.
Wm. Easby, Jr.

Mr. Henry G. Morris read a paper on "High-speed Electric Railroads."

Business Meeting, December 2, 1905.—President Comfort in the chair. Eighty-six members and visitors present.

Past-President Leffmann offered the following resolution, which was unanimously adopted: "That the thanks of the Engineers' Club are tendered to the managing officers and engineers of the Philadelphia Rapid Transit Company and to Mr. E. E. Smith of the Construction Company, for the opportunity to inspect the Market Street Subway."

Mr. Chas. F. Mebus read a paper on "Sewage Purification, with Notes on English and German Works."

Business Meeting, December 16, 1905.—President Comfort in the chair. Eighty-two members and visitors present.

Nominations for officers were presented as follows:

For Vice-President,.....Strickland L. Kneass.
For Treasurer,.....Henry Leffmann.
For Director,.....Allen J. Fuller.
For Director,.....Francis Head.

President Comfort, in introducing the speakers of the evening, referred to the fact that it was the Twenty-eighth Anniversary of the founding of the Club. Mr. Christie then made an address on "Personal Reminiscences of the Past Half-century." Mr. Francis Schumann and Mr. J. M. Hartman then made some remarks on the general subject of Mr. Christie's paper.

The President announced the death of General Herman Haupt, an honorary member of the Club. Mr. John C. Trautwine, Jr., then moved the appointment of a committee to prepare a memorial on the death of General Haupt.

The Tellers announced that Charles B. Fulton, Clinton D. Hoyt, Robert K. Sheppard, and James N. Vandegrift were elected to active membership, and that Lyman P. Clark was elected to associate membership.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, October 21, 1905.—Present: President Comfort, Vice-President McBride, Directors Dallett, Davis, Devereux, Easby, Loomis, and Quimby, and the Treasurer and Secretary.

The report of the Treasurer for the month of September was read and accepted as follows:

Balance August 31, 1905,	$2232.51
September Receipts,	260.30
	$2492.81
September Disbursements,	642.15
Balance September 30, 1905,	$1850.66

The proposal of the Engineers' Society of Western Pennsylvania regarding the exchange of Proceedings was taken up, and upon motion was declined with thanks.

The proposal of the Engineers' Club of Central Pennsylvania that it be included among the list for the exchange of club-house privileges was accepted.

The Secretary read a letter from the City Parks Association requesting a voluntary contribution toward defraying the expenses of the report on Park Systems. The Secretary was instructed to write to the Association that the By-Laws of the Club prohibit it from making any official contribution, but that the matter would be brought to the attention of the Club, so that personal contributions might be given.

Director Loomis reported that the Philadelphia branch of the American Society for Testing Materials had made application for the use of the Club-rooms for their meetings. On motion the application was referred to the House Committee with power to act.

Upon motion the old scheme of annually giving away to members unbound copies of periodicals was declared abandoned, and henceforth such copies will be sent to the University of Pennsylvania Library, in exchange for which members of the Engineers' Club will be allowed the privileges of the University Library, including the borrowing of books from the Library.

A letter was read from Mr. Edwin Clark, Chief of the Bureau of Building Inspection, suggesting that a committee be appointed to recommend standard regulations regarding the construction of buildings in reinforced concrete. Upon motion the President was authorized to appoint such a committee, and also that the committee be requested to present to the Club their deliberations for a topical discussion.

Regular Meeting, November 18, 1905.—Present: President Comfort, Vice-President King, Directors Dallett, Davis, Devereux, Easby, Loomis, and Quimby, and the Treasurer and Secretary.

The report of the Treasurer for the month of October was read and accepted as follows:

Balance September 30, 1905,	$1850.66
October Receipts,	572.85
	$2423.51
October Disbursements,	486.69
Balance October 31, 1905,	$1936.82

The Finance Committee presented a routine report.

It was moved and carried that DeWitt Dukes Barlow be advanced from junior to active membership, he having fulfilled the requirements.

A letter was read from Prof. Marburg, Secretary of the American Society for Testing Materials, requesting the use of the club-house by that Society and the granting of privileges of the club-house to such members as come within the non-resident classification of the Engineers' Club. Upon motion the request was granted.

It was moved and carried that the hours of the clerk be changed from 9 A. M. to 5 P. M., with the understanding that if the work of the office should accumulate so that these hours are insufficient, extra time will be put in.

REGULAR MEETING, December 16, 1905.—Present: President Comfort, Vice-President McBride, Directors Dallett, Davis, Devereux, Loomis, and Easby, and the Treasurer and Secretary.

The report of the Treasurer for the month of November was read and accepted as follows:

Balance October 31, 1905,	$1936.82
November Receipts,	382.50
	$2319.32
November Disbursements,	383.53
Balance, November 30, 1905,	$1935.79

It was agreed that it was the sense of the Board that obituary notices of deceased members should be resumed.

The following resignations were accepted: Clifford R. Buck, Jas. G. Hallsted, Carl Horix, Wm. Jordan, Jr., Edwin R. Keller, Harvey Linton, Samuel R. Marshall, E. H. Mumford, Jno. W. Pollock, A. Wood.

The Library Committee reported a bid from the Girard Bindery at reduced rates from the present figures. On motion the matter was left to the Library Committee with power to act.

It was decided that there should be a meeting of the Board on January 6th at 4 P. M.

ADDITIONS TO THE GENERAL LIBRARY.

FROM L. L. TRIBUS, SECRETARY.

Report of the New York Bay Pollution Commission.

FROM STATE BOARD OF HEALTH, BOSTON, MASS.

Thirty-sixth Annual Report.

FROM SMITHSONIAN INSTITUTE.

Vol. XI, No. 1, Nova Scotia Institute of Science.

FROM EUGENE HAANEL, SUPT. OF MINES, DEPT. OF INTERIOR, OTTAWA, CANADA.

Mica, Its Occurrence, Exploitation and Uses.

Asbestos, Its Occurrence, Exploitation and Uses.

FROM A. GIBB MAITLAND.

Report on Geographical Features and Mineral Resources of the Pilbara Goldfield, Australia.

FROM EMIL I. NEUBLING.

Fortieth Annual Report of Board of Water Commissioners for 1904–1905 of the City of Reading.

THE ENGINEERS' CLUB OF PHILADELPHIA,

House, No. 1122 Girard Street,

PHILADELPHIA, PA.

ANNUAL REPORT OF THE BOARD OF DIRECTORS

For the Fiscal Year 1905

JANUARY 6, 1906.

TO THE ENGINEERS' CLUB OF PHILADELPHIA:

In compliance with the requirements of the By-Laws, the Executive Committee offers the following report for the year ending December 31, 1905:

Eighteen regular meetings of the Club were held, at which the maximum attendance was 303, and the average 97. The increased average attendance for 1905 over 1904 is about 9 members. Ten stated, 1 adjourned and 2 special meetings of the Board of Directors were held.

Twenty-three active, 24 junior, and 4 associate members were elected; 31 active members resigned (14 of which were as of December 31, 1904); 11 junior members were transferred to the active list; 7 active members were dropped from the rolls.

The record of deaths is:—

Francis H. Albright, Active Member, died June 29, 1905.
C. J. Bechdolt, Active Member, died December 5, 1905.
John L. Gill, Jr., Active Member, died November 6, 1905.
Herman Haupt, Honorary Member, died December 14, 1905.
Edward Longstreth, Active Member, died February 27, 1905.
H. C. Luders, Active Member, died July 17, 1905.
R. C. Luther, Active Member, died March 14, 1905.
G. H. Perkins, Active Member, died February 7, 1905.
S. M. Prevost, Active Member, died October 2, 1905.
Raymond W. Smith, Active Member, died May 23, 1905.

	1904.			1905.		
Class.	*Resident.*	*Non-Resident.*	*Total.*	*Resident.*	*Non-Resident.*	*Total.*
Honorary	2	5	7	2	4	6
Active	341	118	459	333	113	446
Junior	8	2	10	18	5	23
Associate	20	...	20	24	...	24
	371	125	496	377	122	499

The following papers have been presented:

JANUARY 7th.	Principles and Applications of Mercury Vapor Apparatus.	F. H. Von Keller.
JANUARY 21st.	Address of Retiring President.	Carl Hering.
FEBRUARY 4th.	Torresdale Conduit.	John W. Hill.
FEBRUARY 18th.	The Design and Operation of a Modern Freight Yard.	Joseph T. Richards.
	A Regulating Valve.	J. W. Ledoux.
MARCH 4th.	The Engineering Development of Manila under American Dominion.	Robt. G. Dieck.
MARCH 18th.	Reinforced Concrete—Some of Its Principles, with Practical Illustrations.	Walter Loring Webb.
	Mercury Vapor Rectifier, Explained and Demonstrated.	E. P. Coles.
APRIL 1st.	Sanitation in Office-Buildings.	Henry Leffmann.
	Reproduction of Drawings of Great Length and Number.	Lino F. Rondinella.
APRIL 15th.	The Electrical Engineer in Heavy Traction Work.	Wm. McClellan.
MAY 6th.	Stereoscopic Vision Applied to Surveying.	E. F. Northrup.
	Recent Developments in Expanding Machinery.	Luther D. Lovekin.
MAY 20th.	Bacteriological Treatment of Sewage.	F. Herbert Snow.
JUNE 3d.	The Angleometer.	Dr. H. E. Wetherill.
	A Simplex System of Concrete Piling.	Constantine Shuman.
SEPTEMBER 16th.	The Microscopic Structure of Building Stones.	Henry Leffmann.
OCTOBER 7th.	A Description of the Elements of the Nernst Lamp and Its Applications.	Chas. A. Barton.
OCTOBER 21st.	The Early History of the Philadelphia Water Works.	John C. Trautwine, Jr.
NOVEMBER 4th.	Sand-Lime Brick.	E. W. Lazell.
NOVEMBER 16th.	High Speed Electric Railroads.	Henry G. Morris.
DECEMBER 2d.	Sewage Purification, with Notes on English and German Works.	Chas. F. Mebus.
DECEMBER 16th.	Personal Reminiscences of the Past Half-Century, with a Special Reference to Developments on the Great Lakes and the Mississippi Borderland.	James Christie.

On January 21st an exhibit was held in the different rooms of the Club House, which consisted of new apparatus, instruments, models, etc., of interest to engineers.

Members and their friends visited and inspected the completed portion of the Market Street Subway on December 2d, as arranged by the Information Committee.

A fire-proof safe was purchased for the use of the office.

The Philadelphia Branch of the American Institute of Electrical Engineers presented to the Engineers' Club a new screen for the lantern, as an evidence of their appreciation in being allowed the use of the Club rooms for their monthly meetings.

The Treasurer's statement of receipts and expenditures has been examined and found correct. A statement is herewith submitted of the net expenditures for the year; also a comparative statement of assets and liabilities at the beginning and end of the year.

NET EXPENDITURES FOR 1905.

House	$2491 67
Library	93 15
Proceedings and Directory	760 43
Information	37 80
Office	634 63
Salaries	1536 00
	$5553 68

ASSETS.

	Jan. 1, 1905.	*Dec. 31, 1905.*
Furniture and fixtures, as per appraisement	$1947 26	$1900 00
Library, as per appraisement	2360 56	2100 00
U. S. Bond, issue of 1898 (par $500), market value	522 50	517 50
On deposit, bearing interest at 3 per cent.	578 43	595 90
On deposit, bearing interest at 2 per cent. (including advance dues)	839 09	2139 56
Outstanding dues considered good and collectable (being dues for the years 1904 and 1905 respectively, remaining unpaid on December 31st, by members in good standing)	555 00	445 00
	$6802 84	$7697 96

LIABILITIES.

Advance dues collected and included in above bank deposits (being dues for 1905 and 1906 respectively)	$595 00	$955 00
NET ASSETS	$6207 84	$6742 96

Respectfully submitted,

SILAS G. COMFORT, *President.*

WALTER LORING WEBB, *Secretary.*

REPORT OF THE TREASURER FOR THE FISCAL YEAR 1905.

Receipts.

Initiation fees (51)	$255 00	
1903 dues	30 00	
1904 dues	480 00	
1905 dues	5090 00	
1906 dues	955 00	
		$6810 00
Proceedings:		
Advertisements	407 00	
Sales	72 25	
Reprints	156 60	
		635 85
House:		
Telephone	13 99	
Billiards	8 10	
Keys	26 45	
		48 54
1905 Directory		584 70
Interest on Deposit		46 62
Interest on Investment		15 00
Total Receipts		$8140 71
CASH BALANCE, DEC. 31, 1904,		**1417 52**
		$9558 23

Expenditures.

Salaries:		
Secretary	$350 00	
Treasurer	115 00	
Clerk	501 00	
Janitor	570 00	
		$1536 00
House:		
Rent	1200 24	
Coal	134 40	
Gas and Electric Light	111 61	
Ice	36 40	
Supplies and Repairs	248 62	
Telephone	186 94	
Insurance	9 00	
Luncheons	613 00	
		2540 21
Office Expenses		634 63
Proceedings		1665 48
Information Committee		37 80
Library		93 15
1905 Directory		315 50
Total Disbursements		6822 77
CASH BALANCE, DEC. 31, 1905,		**2735 46**
		$9558 23

Respectfully submitted,
GEO. T. GWILLIAM, *Treasurer.*

PHILADELPHIA, January 3, 1906.

We have examined the books and accounts of the Treasurer, compared them with the original vouchers, checks and bank books and found them to correspond with the Treasurer's statement submitted above.

H. W. SPANGLER,
FRANCIS HEAD, } *Auditors.*

JANUARY 13, 1906.

Silas G. Comfort

TWENTY-EIGHTH PRESIDENT OF THE CLUB. JAN. 14, 1905–JAN. 20, 1906.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XXIII. APRIL, 1906. No. 2

PRESIDENT'S ADDRESS.

THE UNIFYING OF THE REPUBLIC.

Delivered January 20, 1906.

THE advance made in engineering development and achievement during the last thirty years warrants the conclusion that no other three decades in our history can compare with those now closing. Since the celebration of the one hundredth anniversary of the signing of the Declaration of Independence, industrial and commercial conditions have been revolutionized. Indeed, the changes made in a generation have been so many and so great that it is well-nigh impossible to measure them adequately.

Horse-car lines for city service, supplemented later on by cable roads, have given place to the electric street railway. Surface lines no longer monopolize city passenger traffic. Electric surface roads, elevated roads and subways are continually extending the limits of the suburbs of our great cities, and ever lengthening the practicable distance between the residence and place of business of the worker. The bicycle has come and gone, to be succeeded by the automobile. The air brake, in conjunction with the automatic coupler, has rendered the control of heavy trains easy, and the brakeman has become the trainman. The Vestibuled Limited, with its through sleeping- and dining-car service, a veritable luxurious hotel on wheels, makes long-distance travel an occasion of pleasure, rather than an event to be dreaded. Steel and masonry structures have supplanted iron and wooden bridges; and iron rails have disappeared from the

most insignificant railways. The Niagara Cantilever Bridge and the East River Suspension Bridge have ceased to cause wonder; they no longer represent the highest designing ability or the best constructive skill of the bridge engineer.

Again, the last quarter of a century has witnessed the invention and the putting into daily use of the electric light and the telephone. How would the average person of a generation ago have regarded the prophecy that but a few years were to elapse before the industrial captain, sitting in his office, would speak his orders directly to his subordinates a thousand or more miles away?

The handling of ore at the Lake Superior mines, and the methods of its transportation by the route of the Great Lakes, is little short of marvelous. It may be said that with these and other improved methods of ore-handling and steel-making, no hand labor is needed today from the time the ore leaves the mines, on the shore of Lake Superior, until the finished product, the steel rail, comes from the rolls in the Pittsburgh district.

Great natural water-courses, notably that at Niagara Falls, are being utilized for power. It is said that this great cataract is capable of developing seven million horse-power, and of this, nearly one-seventh is practically ready for delivery. Buffalo has thus far been the one large city to benefit directly by the cheap electric power thus generated, but with the output greatly increased, as it will be in the near future, hundreds of factories and industrial establishments will be attracted to this locality, where power is to be obtained at a low figure. Furthermore, with the present means for transmitting electric currents, cities within a radius of 100 miles or more of the Falls will probably be furnished with light, heat and power; so, too, also street railways and even railroads now operated by steam. In fact, with the looked-for improvements in the methods of transmitting electricity, it is not entirely beyond the range of possibility that the Niagara Falls power plants may, at no distant day, furnish power to operate the great New York Central System from Buffalo to Albany, and even to New York.

The office building, with its towering height, made possible by steel and fire-proof construction and improved elevator service, has revolutionized city business life, and added another element to the evolution of concentration.

Cement and concrete, by replacing wood and displacing brick and stone as building materials, and the use of asphalt as the most desirable

material for street paving, give reason to conclude that the "Age of the Plastic Materials" is indeed at hand.

Great railroad corporations are planning and executing vast changes in alinements and terminals, in order to handle increasing traffic, both passenger and freight. Among those that have especially interested the profession are the New York Central and Hudson River Railroad Terminal at New York, the Pennsylvania System's Hudson River Tunnel and its Metropolitan Terminal, and the joint improvements by the Baltimore and Ohio and the Pennsylvania at the national capital. It is estimated that the total monetary outlay in the improvements recently completed, in course of construction, and planned at the present time by all the railway systems of the country, is close to one billion dollars.

It would require time far beyond that at my command to name in even briefest detail the inventions and discoveries the adapting of which to practical use has revolutionized social and commercial conditions; created new forms of activity; and furnished new means of gaining a livelihood to thousands of toilers. An additional example, however, will not be amiss.

As illustrating the commercial value of a mere change of form, take the refrigerator-car. Upon it, as developed and improved since 1888, when the first "ice box" on wheels was sent to California, rests the prosperity of a wide section of our country. This is summed up by Ray Stannard Baker in a recent magazine article: "Because of it not only California oranges, but Georgia and Michigan peaches, and Florida strawberries are commonly served in New York, Montreal, and even in London and Paris. . . . . Upon the refrigerator-car rests the prosperity of all the great slaughtering centers of the West: it enables Kansas City to display its choice roasts in the markets of Arizona, Liverpool and Yokohama. And, by stimulating the concentration of cattle-killing, it has made possible the economics by which the packer utilizes every part of the steer or hog. No better illustration of the peculiar dependence of industry upon transportation could be given than that of the packers and fruit-growers. The mere form of car has completely revolutionized both of these industries."

Living as we do in the midst of the social, industrial and economical conditions of this, the twentieth century, it is difficult for us to realize those prevailing at the beginning of the nineteenth. It is my purpose, however, to endeavor to place before you a view of the surroundings of our forefathers a century ago, and to consider briefly the

advancement made by them during the third of a century beginning approximately with the year 1800. Facing problems sufficiently vast to discourage the stoutest heart, verily, they appeared to accomplish the impossible. By their native ability, shrewdness and superb self-confidence, they laid well the foundations upon which has been reared the structure of national unity, greatness and achievement.

According to the census of 1800, the United States of America contained 5,303,843 persons; of these, nearly one-fifth were negro slaves. As yet the land was untamed; forest was everywhere, except here and there comparatively small sections under cultivation; the great natural resources lay undisturbed—the timber uncut and the minerals still in their rocky beds; the great majority of the people were still within fifty miles of the ocean, where alone the wants of man could be obtained with comparative ease. The center of population was 18 miles south of Baltimore. West of the Alleghenies, the entire population numbered about half a million. In the space between there lay a vast region but sparsely settled, and scarcely more easily penetrated than in the days of the early explorers. Only three great wagon roads crossed the mountains: two in Pennsylvania; one connecting Philadelphia and Pittsburgh, and one leading from the Potomac to the Monongahela; while the third passed through Virginia southeastward to the Holston River and Knoxville, in Tennessee.

The people west of the Alleghenies were partly disposed to think themselves capable of forming a separate nation, and the original thirteen States were not altogether unwilling to agree. Burr's scheme for a southwestern empire possibly might have been other than a visionary dream had he laid his plans a little differently a few years earlier. Geographical conditions have proved important factors in the genesis and development of nations, and, with the slow communication of the time, an independent empire with an outlet to the Gulf was not entirely beyond the range of probability.

Roads were few and bad, the rivers were in many instances difficult to navigate, as also to cross. Indeed, even along the seaboard communication by water was slow and irregular. The voyage to England from Boston was comparatively more easy and comfortable than that from New York to Albany. If the heterogeneous elements constituting the United States were to be welded together into a homogeneous whole, it must be done by closer intercommunication. As yet the original States were scarcely more closely bound together commercially than they were when they declared themselves free and indepen-

dent. Their natural commercial ties grew but little more rapidly than those which united them severally to Europe. New England, for instance, had little in common with Virginia, and neither one could appreciate the good qualities of the other.

The farms of eastern Pennsylvania, the Connecticut Valley, Long Island, and other favored localities, were far in advance of those of the greater portion of the country. The man who in the year 1800 ventured to hope for a new era could lay his hand on no statistics that silenced doubt. In most respects the farmer of the twelfth century enjoyed most of the comforts of those of the eighteenth. Even in New England the farmhouse was scarcely so well built, so warm or so spacious as that of the well-to-do contemporary of the Conqueror. The clothing of the farmer was homespun. The plow was old and clumsy; the sickle was used much more commonly than the cradle; threshing was done with the flail, while in Virginia the grain was still commonly trodden out by horses. Swine ran loose, and in the colder regions stock was not housed until after the later frosts; and it is still related that in New England the ordinary cultivator of the soil was known to remove his barn on account of the manure that had accumulated around it, although the soil was not so rich as to warrant neglect to enrich it. New England was the center of such manufactures as existed, but the product was small and consisted largely of what were termed "Yankee notions." As yet, Old England supplied the ordinary manufactures much more cheaply than Massachusetts could do.

The then great cities were Boston, New York, Philadelphia, Baltimore and Charleston. The shipping of Boston exceeded that of Philadelphia and New York combined. New York was badly paved and undrained. The Manhattan Company was laying wooden pipes for a water-supply, but no sanitary regulations were enforced, and every few years yellow fever claimed many victims.

"Philadelphia," wrote the Duc de Liancourt, "is not only the finest city in the United States but may be deemed one of the most beautiful cities in the world." Our city was even then fairly well paved and partly drained. The repeated ravages of yellow fever had roused the inhabitants to a regard for sanitary precautions, and steps were being taken to provide for an adequate supply of pure water.

Washington was magnificent in plan, and in this respect only was worthy to rank as one of the great capitals of the world. When the Government was transferred from Philadelphia, in 1800, the partly

finished White House stood in a field overlooking the Potomac, with a few brick buildings near it; while across a swamp, a mile and more away, the unfinished Capitol arose. The vastness of the plan showed that the founders understood the magnitude of the task before them. Only by lavish expenditures on the part of Congress could the plans be carried out. Three-quarters of a century were to pass before the national legislature awoke to the importance of making the capital a great and worthy symbol of the power and resources of the nation—a city to rank in splendor with the great capitals of Europe.

Further south, Charleston enjoyed great prosperity, and there was much to support the view that at no distant day she would outstrip her northern rivals in the contest for commercial supremacy. The application of the steam-engine of Watt to the spinning and weaving of cotton in England, and the almost simultaneous invention of the cotton-gin by Whitney, created a great demand for this staple. Land which had been worthless in South Carolina suddenly acquired new value, so that in 1800 nearly every planter in the Carolinas was growing cotton, buying negroes and putting increasing areas under cultivation. Neither Boston nor Baltimore had a larger region to draw from, nor so profitable a raw material for export. In 1791 the amount of cotton shipped abroad was about two hundred thousand pounds. This grew to twenty millions in 1800, while in 1803 it had reached forty millions.

Looking backward, however, we may find the premises which, logically applied, make clear that the new nation had but little to fear as to the outcome of its struggle for national existence, national unity, and national progress along all lines of activity. The new world of 1800 is found to be fundamentally different from the old. Not without a semblance of a true conception of impending changes did the House of Representatives in 1796 debate upon the insertion of a note in the reply to the President's speech to the effect that the nation "was the freest and most enlightened in the world." Without question the freest; no large standing army thinned the ranks of the producers; no great national debt, incurred by preceding generations for the gratification of the pleasures and ambitions of a reigning house, weighed down the nation. Church and State were separated. Man was face to face with his Creator.

Says an eminent writer: "From the highest to the lowest, with the exception of negro slavery, American society was sound and healthy. Stripped for the hardest work, every muscle firm and elastic, every ounce of brain ready for use and not a trace of superfluous flesh in

his nervous and supple body, the American stood in the world a new order of man."

What, then, were the means by which national unity was acquired, —what were the factors in producing the "era of good feeling," culminating in 1821 by the re-election of James Monroe as President of the United States, by the unanimous vote of the electors? They are four: the Louisiana Purchase, the results of the war of 1812, the work of the Supreme Court, and the achievements of the "Fathers of the Engineering Profession in America."

On the 4th of March, 1801, Thomas Jefferson came from his own lodgings to the capital on foot, in his ordinary dress, to be inaugurated as the third President of the United States.

The shores of Florida, Louisiana, Texas and Mexico were Spanish; Pensacola, Mobile and New Orleans closed all rivers by which the United States could reach the Gulf. The valley of the Ohio, up to Pittsburgh, was at the mercy of this foreign ruler. All the produce that floated down the Mississippi, or other streams that emptied into the Gulf, must pass under the Spanish flag. And every southern and western State looked to the military occupation of Mobile, Pensacola and New Orleans as a future political necessity.

The right of navigation of the Mississippi had been conceded by treaty in 1795, and with it the right to the free use of the port of New Orleans until some other convenient harbor should be allotted. Five years later Spain ceded all Louisiana to France. The treaty, however, was kept secret until 1802, when it became known in the United States as an assured fact. Jefferson, whose sympathies were always strongly French, at once wrote our minister to Paris, Robert R. Livingston, as follows:

"The Cession of Louisiana and the Floridas by Spain to France works most sorely on the United States. . . . . It completely reverses all the political relations of the United States. There is on the globe one single spot, the possessor of which is our national and habitual enemy. It is New Orleans. . . . . It is impossible that France and the United States can continue long friends when they meet in so irritable a position. . . . . The day that France takes possession of New Orleans fixes the sentence which is to restrain her forever within the low-water mark. It seals the Union of two nations, who, in conjunction, can maintain exclusive possession of the ocean. From that moment we must marry ourselves to the British Fleet and nation."

The President's efforts were then directed towards gaining New Orleans from France by peaceful means. But at this most inopportune time, in October, 1802, the Spanish Intendant at New Orleans issued an edict in direct opposition to treaty stipulations, cutting short the American privileges at the port. At once the spirit of the Western country was aroused. The pioneers talked of marching at once for attack on New Orleans. Wiser counsel, however, prevailed. The House of Representatives took up the matter, and under the leadership of John Randolph, the President was given authority to effect such purchase as would best conserve the interests of the South and the West.

Jefferson's plans included the purchase of New Orleans and some territory to the eastward, and James Monroe was appointed a special envoy to join with Livingston to bring about the desired result. And now, at this critical juncture of affairs, the Treaty of Amiens, between France and England, is about to be broken. Napoleon needs money for vast military expenditures, and he offers the imperial province of Louisiana, upwards of a million square miles in area, for a pittance of fifteen millions of dollars. The splendor of American destiny sweeps over the plains of the West, up the slopes and to the snowy crest of the Rocky Mountains.

When Livingston set his name to the Purchase Treaty paper, he rose and shook hands with Monroe and Marbois, the French minister, and said, "We have lived long, but this is the noblest work of our lives." Remember, this was spoken by a man who had been a member of the committee appointed to draft that immortal paper, the Declaration of Independence.

Upon receipt of the draft of the treaty, the President's first thought was of the Constitution. The plain truth, known and read by all men, was that Jefferson had thrown aside his previous theories. In the words of one of his biographers: "Destiny, that goddess who loves nothing so much as irony, had led him to the point to which she so often leads the profoundest statesmen and the wisest philosophers, the point where the choice must be made between a sound abstract doctrine and a sensible act inconsistent therewith. In the dilemma Jefferson did what all really great statesmen and philosophers always have done and always will do in such an emergency; he turned his back upon the doctrine and did the act. He preferred sound sense to sound logic, and set intelligent statesmanship above political consistency."

The debates in Congress on the constitutionality of the proceeding were interesting; but we are concerned alone with the result. Congress made the necessary appropriations, and provided for the temporary government of the Territory, investing the President with all the powers of the late Spanish monarchs. The essential point is, that for the first time in our national history all the parties agreed in admitting that the national government could govern. Thus the Louisiana Purchase proved a welding and a unifying influence in domestic interests of incalculable value.

In 1803 war broke out anew in Europe, and the ill effects on American commerce were soon felt. Jefferson labored to maintain a pacific neutrality despite frequent outrages by vessels of both England and France, it being the evident purpose of the belligerents to force the United States to forego the commercial advantages attending neutrality. The victory of Trafalgar, in 1805, made England supreme upon the ocean, and the situation grew worse, the climax being reached in June, 1807, in the audacious attack of the English war-ship "Leopard" on the American frigate "Chesapeake," just outside Hampton Roads. This enraged the nation, but the President still clung to his aversion of war. A message to Congress results in the famous Embargo,—a remarkable piece of statecraft: not war, but commercial oppression; American shipping protected by keeping it at home; trade with the belligerents forbidden in order to deprive them of American products. To be effective, it should have been followed by immediate preparations for war.

Josiah Quincy, of Massachusetts, in speaking of the Embargo, said on the floor of Congress: "An experiment such as is now making was never before—I will not say tried—it never before entered into the human imagination." Continuing, he said: "There is nothing like it in the narration of history, or in the tales of fiction. All the habits of a mighty nation are at once counteracted. All their property depreciated. All their external values violated. Five millions of people are engaged. They cannot go beyond the limits of their once free country; now they are not permitted to thrust their own property through the gates."

What wonder that the stricken industries of the upper Atlantic coast cried for relief, even at the cost of the Union of the States!

But the national patience is at last exhausted, and under the leadership of such enthusiastic young men as Clay and Calhoun, Congress declared war. Totally unprepared, being without adequate navy,

trained soldiery, or military leaders, the nation embarked in a war the results of which, from a human standpoint, could but be most disastrous to the young republic. Strange, too, that war was declared at a time the most favorable in seven years for a diplomatic settlement of difficulties along peaceful lines.

In commenting on the feelings after the signing of the Treaty of Ghent, Henry Adams says: "Only by slow degrees the country learned to appreciate the extraordinary feat which had been performed; not so much by the people as by a relatively small number of individuals. Had a village rustic with one hand tied behind his back challenged the champion of the prize-ring, and in three or four rounds obliged him to draw the stakes, the result would have been little more surprising than the result of the American campaign of 1814. The most intelligent and best educated part of society in the United States and in Great Britain could not believe it, and the true causes of British defeat remain a subject of conjecture and angry dispute."

Hull, Perry and Decatur are the names to conjure with. For the first time England had found foemen that could outfight her in naval conflict; foemen that successfully disputed her title of "Mistress of the Seas." Eminent Englishmen acknowledged that in the rapidity and precision of their fire the Americans were their superiors. According to Sir Francis Head, "Gunnery was in naval warfare in the extraordinary state of ignorance we have just described, when our lean children, the American people, taught us, rod in hand, the first lesson in the art." The English text-book on "Naval Gunnery," written by Major-General Sir Howard Douglass, immediately after the peace, devoted more attention to the new sea power across the Atlantic than to all the naval battles of the Napoleonic wars. The riflemen of America held no second place in marksmanship to that of their brethren on the high seas. Thus demonstrating the great fact that, after all, it is the man behind the gun that decides the conflict.

Politically, the second war for independence established the claim of the United States to a place in the family of nations; while indirectly her prestige as a nation willing and able to defend her interests made possible the Monroe Doctrine, that great guardian principle of American rights and American sovereignty.

Another very significant result of the war was the sudden development of scientific engineering in this country. The United States Military Academy at West Point was established in 1802, and, at the outbreak of hostilities, graduates constituted a majority of the Engi-

neer Corps of the U. S. Army. It is a rare tribute to the wisdom of its foundation that no one of the fortifications constructed by a graduate of the Point was captured by the enemy. Had an engineer officer been given charge of the defenses at Washington, that city would not have been looted and burned by the vandal soldiers of the English commanders, Ross and Cockburn.

It is fitting that we make record of early American military engineers who so honored our profession. Colonel Joseph Gardner Swift, of Massachusetts, the first graduate of West Point, planned the defenses of New York harbor. Lieutenant-Colonel Walker Keith Armistead, of Virginia, the third graduate, was engineer in charge of the construction of the defenses of Norfolk. Major William McRee, of North Carolina, Chief Engineer to General Brown, constructed the fortifications at Fort Erie, that cost the British General Drummond the loss of half of his army. Captain Eleazer Derby Wood, of New York, built Fort Meigs, a point of defence that enabled Harrison to defeat the attack of Procter in May, 1813. Captain Joseph Gilbert Totten, of New York, Chief Engineer to General Izard at Plattsburg, directed the fortifications that stopped the advance of Provost's great army in its movement south from Canada.

Congress during the war had been forced to strong legislation, thus further centralizing power, and accustoming the people to look to the Federal Legislature, so that the time was nearly although not quite ripe for the inauguration of vast internal improvements, the expense of which was to come from the national purse.

When peace came, and the blockade of the coasts was raised, every seaboard city was able to resume at once its commercial habits. The harvests of two seasons were ready for immediate export, and the markets of Europe were ready to receive them. Every man found occupation and capital sought its old channels. In fact, so quickly did the returns from sources of wealth awaiting development come in, that the ill effects of war times soon ceased to be remembered, and political passions were transferred into agencies for great scientific and industrial progress.

The greatest official act of President John Adams—the greatest because of its contribution to the future well-being of his country—was the appointment of John Marshall as Chief Justice of the Supreme Court of the United States.

The task assigned Marshall was the herculean one of construction. It was no less a labor than to interpret, formulate and correlate the great

principles of constitutional law upon which must ever rest the fabric of our government. It was throughout constructional work, calling for judicial character of rarest breadth and power.

"Fortunately," says a biographer, "he had to a very striking degree the constructive faculty, a rare gift and certainly the highest form of intellectual ability which lawyers can ever use and display. He was a builder from the very foundations of a vast edifice by wholly new rules under entirely novel exigencies, and for ends and purposes never before sought."

Once in alluding to the common expression of the Chief Justice, "It is admitted," Daniel Webster remarked to Justice Story, "When Judge Marshall says, 'It is admitted,' sir, I am preparing for a bomb to burst over my head and demolish all my points."

At this early period the warfare between those contending for a strict construction of the Constitution, and those opposed to such, needed a wise, a learned, a just guide. In the volumes covering the records of the Supreme Court, during the thirty-four years of his services as Chief Justice, the decisions in the cases involving international and constitutional law are characterized by the force and clearness of his intellect. Such was the assent of his colleagues on the bench to his supremacy in the exposition of constitutional law, that a dissenting opinion was almost unknown.

The rule which he considered should guide in the construction of the Constitution appears in a number of his leading decisions. As an example, in one case, he expounds incidentally this rule.

"To say," he observed, "that the intention of the instrument must prevail, that this intention must be collected from its words, that its words are to be understood in that sense in which they are generally used by those for whom the instrument was intended, that its provisions are neither to be restricted into insignificance, nor extended to objects not comprehended in them nor contemplated by its framers, is to repeat what has been already said more at large, and is all that is necessary."

In justice to this great character, I must be permitted to extract at some length from a recent biography, that together we may enjoy a contemplation of one of the noblest minds that has contributed to the power and stability of the American Republic.

"To travel over a road paved with authorities and lined out by adjudications is a much simpler task than to cut a new road in a strange territory. . . . . To construct law, to frame in any department

a system of jurisprudence, are tasks which call for an intellect of the highest order. The few judges who have performed such labors, Holt, Mansfield, Marshall, are the really great juridical lights. It may seem that it was comparatively simple for Marshall, in any case of entirely novel complexion, to say, It is—or, It is not—within the Constitution. But to support the decision by an opinion professionally and technically satisfactory, framed in accordance with the spirit of English law, consonant with its fundamental principles, to make it really satisfactory as a judicial opinion and not to leave it either as a ruling or an argument, was a much more difficult undertaking, which none save lawyers could fully appreciate. To deliver many such opinions, which, though upon distinct questions, should yet so combine and harmonize as in conjunction to create a system of constitutional law, was an achievement to which few judges who have ever lived could prove competent. The legal cast of mind must exist in a rare degree; the judicial faculty, an intellectual gift far beyond mere impartiality, must have an extraordinary development; great mental reach and scope, much exceeding what is usually admired as clearness of mind, are indispensable. The judge who rears such a monument to his memory will never be forgotten: in the united domain of English and American jurisprudence there are not half a dozen such memorials; but not the least distinguished is that of Marshall."

The three engineering achievements that present themselves as important factors in the unifying of the nation are: the application of steam as a motive power; the construction of canals, culminating with the opening of the Erie Canal; and the introduction of railroads.

Previous to 1800, John Fitch, a citizen of Bucks County, Pennsylvania, a watchmaker by trade, experimented on the subject of the steam-engine. He appears to have possessed no knowledge of the work of others, and it is said that he made everything that he needed in his experiments. In 1787 his efforts resulted in a steam-boat with which he successfully navigated the Delaware River, and three years later was conducting a passenger service between Bordentown and Philadelphia. Fitch, however, was greatly in advance of the times; the public failed to support him, and with the exhaustion of his means he finally became a wanderer among men, and, broken-hearted, died a suicide in Kentucky before the end of the century.

In 1803 the American Philosophical Society received a communication from the Philosophical Society of Rotterdam, requesting to know what improvements had been made in the construction of the

steam-engine in the United States. The subject was referred to Benjamin H. Latrobe. In his report he said:

"During the lassitude of mechanical exertion which succeeded the American Revolution, the utility of the steam-engine appears to have been forgotten; but the subject afterward started into very general notice in a form in which it could not possibly be attended with much success. A sort of mania began to prevail, which indeed has not yet entirely subsided for impelling boats by steam-engines. . . . . There are indeed general objections to the use of the steam-engine for impelling boats from which no particular mode of application can be free. These are, first, the weight of the engine and the fuel; second, the large space it occupies; third, the tendency of its action to wrench the vessel and reader it leaky; fourth, the expense of maintenance; fifth, the irregularity of its motion and the motion of the water in the boiler and cistern, and of the fuel vessel in rough water; sixth, the difficulty arising from the liability of the paddle or oars to break if light, and from weight, if made strong. . . . . I am well aware," he continues, "that there are still many very respectable and ingenious men who consider the application of the steam-engine to the purpose of navigation as highly important and as very practicable, and who would feel themselves almost offended at the expression of an opposite opinion."

Within four years the steamboat was running, and Latrobe was its warmest friend. Fulton solved the problem of water communication, and thus made practicable cheap and sure transportation by nature's highways.

The Baltimore and Ohio Railroad Company first comes into history as a common carrier in 1827 with a charter modeled after that generally issued to turnpike companies. The honored name of Charles Carroll appears as that of the one who laid the first stone of the tramway. The first division was opened with horses for traction, but it was hardly in operation, when Peter Cooper carried the directors of the company as his guests from Baltimore to Ellicott Mills in cars drawn by the locomotive he had constructed—the first developed by an American mechanical engineer. This occurred in 1830; the speed was eighteen miles an hour. The horse has been superseded and steam stands forth in form complete, for unrivaled service in national unification.

Canals occupied the attention of the colonies before the Revolution. As early as 1750, a scheme for inland navigation was proposed which

illustrates duly the enterprise and daring of the advanced minds of that day. The purpose of this scheme was to unite the Delaware River with the Ohio and Lake Erie. The magnitude of the project is apparent when we consider that it involved a route of about 580 miles and the surmounting of some 3000 feet at the Allegheny Mountains. In part fulfilment, twelve years later surveys were made and levels taken by David Rittenhouse and Dr. William Smith for a canal between the Schuylkill and Susquehanna by way of Swatara and Tulpehocken Creeks; but the colony was just recovering from the losses incident to the French and Indian War, so that nothing came from the project immediately. Then comes the first survey for a canal to connect the Chesapeake Bay with the Delaware River. And in 1769, the provincial legislature authorized a full survey of the Pittsburgh and Lake Erie route as proposed by Rittenhouse and Smith in the original plan to connect the great inland waterway with the Atlantic coast, and there is great probability, had not the minds of all been absorbed by the stirring events of the Revolution, that these projects would have been started. All this is to be credited to Pennsylvania.

Time forbids mention of many other projects for giving access to the western country by means of water routes, and of the successful work accomplished in way of local artificial water-ways in the years succeeding the Revolution and prior to the close of the War of 1812. Suffice it to say, Pennsylvania, Virginia and the Carolinas were building turnpikes and canals, intent upon crossing the mountains to secure the great commercial rewards awaiting them beyond, only to find at last that the coveted end had not been attained, for their way was not the way.

But there was a way. A great level and fertile district, through which the great channel might pass,—must pass; yes, the way from the upper Hudson due west to Lake Erie, and the boundless resources of the Western Reserve will come to market and man will have pushed the frontier beyond the Mississippi. So obvious was the need of such a canal that it was never out of men's minds, even before the war; and no sooner did peace return than the scheme took large proportions. True, when first proposed by Gouverneur Morris in 1803, the project was regarded as "the effusion of an eccentric mind indulging in romantic and visionary schemes." But very shortly the conspicuous advantages of the route rallied a powerful support. The guns of Waterloo are but silenced and the great Napoleon, that had sold us Louisiana, is on the way to St. Helena, when the Board of Canal Commissioners of

New York State employs engineers, fixes the dimensions, and decides all matters preliminary to the actual construction of the Erie Canal. The work was inaugurated by De Witt Clinton, who broke ground at Rome, July 4, 1817, and the canal was completed through to Lake Erie on October 26, 1825. The effect of the opening of this great waterway on the commercial future of the country is not to be over-estimated. The transportation charges overland were almost beyond belief,—one hundred dollars a ton from New York to Buffalo,—and the length of passage twenty days. As illustrating the commercial value of the canal an important commercial report made twenty-five years after the opening, in comparing the then existing conditions with those antecedent to the building of the canal, says: "Upon the very route through which the heaviest and cheapest products of the West are now sent to market, the cost of transportation equaled nearly three times the market value of wheat in New York; six times the value of corn; twelve times the value of oats; and far exceeded the value of most kinds of cured provisions."

In the presence of this first supreme triumph of the American civil engineer, are we to think merely of commercial benefits? Does our great profession confer upon the world only material advantages? In the booming of the guns that signaled the opening of the Erie Canal do we not hear the glad greeting of the merchant, mechanic and shipmaster of the East to his countrymen far distant in the golden harvest fields of the West? Verily, the dream of an independent empire beyond the Alleghenies is at end.

In addition to all this, the Erie Canal must ever appeal to the American engineer as an enterprise of peculiar and suggestive interest. The abounding faith of the American of that day in the ability of his fellow-American to direct and to accomplish has no finer illustration than in the action of the Canal Commission when it determined to entrust the work of construction entirely to native talent. What amazing self-confidence steadied the steps and nerved the arm of the builders of this nation! Who did the work for the Commission? Not trained engineers; but men of sterling integrity, intense singleness of purpose, unconquerable resolution, and, above all, possessed of that rare order of ability that solves new and untried problems. Let it be observed that now, as then, these qualities characterize the master in all departments of human achievement.

The canal completed, the railroad comes into view, the field widens, the problems become great, perplexing, national. The engineer is at

the forefront, and when his line of steel crosses the Rocky Mountains down to the shores of the ocean, the Empire State hails her sister State at the Golden Gate of the Pacific, and the Republic is one and indivisible.

The engineer has wrought with the soldier and the statesman, that the hope of the great Webster, voiced in patriotic fervor, might be realized:

"Let my last feeble and lingering glance behold the glorious ensign of the Republic, now known and honored throughout the earth, still full high advanced, its arms and trophies streaming in their original luster, not a stripe erased or polluted, not a single star obscured."

ANNIVERSARY MEETING, DECEMBER 16, 1905.

The President.—To-night is the Twenty-eighth Anniversary of the founding of The Engineers' Club of Philadelphia, and it is most fitting that the event should be commemorated. While no formal exercises have been planned, it would seem that the Information Committee had the day in mind in arranging for the program of the evening—"Personal Reminiscences of the Past Half-Century," by a number of our older and most honored and experienced members.

The date of the founding of the Club was December 17, 1877. Of the original twenty-one, three—C. E. Billin, Wilfred Lewis, and M. R. Mucklé, Jr.—are still identified with the organization; while the Official List shows fourteen others that have been active members for more than a quarter of a century.

In recent years two of your Presidents have given exhaustive histories covering the founding and growth of the Club, so that detailed reference to this matter is unnecessary at this time. The growth of the Club has been steady since its foundation. As the old members have dropped out or crossed the Great Divide, others have succeeded them, taking up the burden and carrying forward the work to successful fruition.

This is said to be the age of young men. Often the question presents itself, What of the old men? What place have they in the work of development and progress? True, conservatism is not a distinctive quality of youth, and where daring and a fearless launching out into new and untried fields are called for, youth may be needed. In our great profession, however, experience must ever count for much, and he is best equipped who while recognizing new conditions is able to bring to bear upon the questions arising therefrom the ripe judgment that can be acquired only by years of successful endeavor. For the safety of the future we must not be either too quick to cast off the old or too eager to take on the new; but always should remember that we can never get beyond the stage of learning. The best teachers are those who have been tried and not found wanting.

I repeat, this evening's program is peculiarly fitting in that, while it may be considered a commemoration of the founding of the Club, it gives to us, of the younger generation, this opportunity to express our appreciation of the wisdom and worth of our older members; and,

furthermore, to assure them that whatever the popular notion, we recognize that without the wise guidance that can come only from the experienced, our profession would be retrograding rather than advancing.

I have the pleasure of calling on our honored ex-President, Mr. James Christie.

PERSONAL REMINISCENCES OF THE PAST HALF-CENTURY.

JAMES CHRISTIE.

On this our twenty-eighth anniversary, and the holiday season of the year, I venture to depart from the rigid lines of a strictly technical paper to offer some rambling remarks on the industrial conditions of our country at a time which probably antedates the experience of most of our members. It was my intention to have with us several of our veteran members, whose occasional presence is always a source of pleasure, and whose experiences are more abundant and preceded mine.

I very much regret that endeavors to this intent proved less satisfactory than was hoped. Advanced years, physical infirmity, or other engagements have prevented the attendance of several honored members, but who have expressed in writing their interest in the subject, and regrets for their absence.

You will remember this is simply a literary holiday ramble, you will allow due license for the garrulity of age, and the necessity of reflecting on scattered facts and generalities somewhat vague, as we have to compress much within the compass of an hour.

The development of this country, to those of us who can recall the past half-century, seems like pages of fiction, and only by contrasting events of the past with those of today can we realize the material growth that we have undergone.

As a boy I have watched the nomadic Indians repair their bark canoes and put up their tents on land where now stands the palatial capitol of a flourishing State. I have traversed a wilderness where now exists a populous city, the seat of a university, and vividly recall northern communities practically isolated by the rigors of winter where now the omission of daily mails or a break in intercourse by wire-transmission would create confusion and much discontent.

The first half of the nineteenth century witnessed the rise and decline of the canal system of the country. The railroad system can only be said to have passed the experimental stage at the close of the same era. The stream of emigration clung largely to the waterways until the forties and fifties of the century, when transportation by rail offered facilities for travel heretofore unknown, and gave a great impetus

to that migratory movement which denuded the farms of New England, as well as Old England, and poured into the mighty West those multitudes who proceeded diligently to till the prairies, level the forests, and delve the mines of hidden wealth which have so materially affected the industrial history of the world. Caught as a boy in 1856 in this stream of westward migration, I traversed the St. Lawrence and the Great Lakes, down the Mississippi as far as St. Louis, and westward to the borders of Kansas and Nebraska.

It is of my recollections of this period of practically fifty years ago that I wish to speak. The period of 1855 or '56 was somewhat of a memorable one. At this time the population of the country was about twenty-five millions of people, and there were then in existence some twenty thousand miles of railroad. In that same period—1855 or '56—Henry Bessemer announced to the world his discovery of the pneumatic process of manufacturing steel. In the same year the first locks were built at Sault Ste. Marie, making a navigable water-course between the upper lakes. In the year before that—1854 or '55—mailed ships, which were really old wooden vessels ironclad, were first used in the Crimean War, and the experience gave a great impetus to the modern ironclad. At about the same period the great engineer Brunell was at the height of his activity, and in conjunction with Scott Russell in England was busily engaged in building the "Great Eastern," which made her voyages a few years later with not very much success. Those were the days before the introduction of multiple expansion high-pressure engines, nor was the future of the screw propeller definitely assured. However, they fitted her with both side-wheels and propellers, so that if one system failed the other could be relied upon.

Within a few years previous to the time of which I speak—1855 or '56—St. Louis and Chicago first made railway connections with the East, although the great Pennsylvania line was not completed until a few years later. Few railways existed west of the Mississippi except in Iowa and Missouri. Beyond that, there were no railroads in Kansas or to the west, and the great Pacific roads came many years later. Modern methods for facilitating through travel had not been established, and freight rates were very high, many fold higher than our present rates. The rate on grain was 50 cents a bushel between Chicago and New York, whereas it is now 9 cents all rail, or a little over 6 cents by water and rail.

The railroads in the West had a very precarious existence; they

were built in the cheapest manner, and often in advance of the needs, that is, the population followed the building of the railroads. Their existence depended usually on public grants, and they very frequently defaulted upon their bonds and rarely paid dividends, and we can realize the great change since that period, as the railroad earnings of the country are now approximately $2,000,000,000 and the dividends paid are about $600,000,000 a year.

It is not my intention to discuss the early history of the Great Lakes. Suffice it to say that there was a large amount of sporadic traffic on them in early days. Even on Lake Superior some trade was carried on by the Hudson Bay Company during the previous century.

Navigation of the upper St. Lawrence and the Great Lakes had no definite form until after 1800. About that time the growth of the country seemed to justify the establishment of greater facilities for traffic, and shortly after that, the application of steam to boats gave a great impetus to trade, and then followed the construction of the Erie Canal, the Welland Canal, and others, which were all important factors in the stimulation of lake navigation. About 1840 the first screw propellers were put on the lakes. Several vessels were built at Oswego, and they formed the early beginnings of screw-propelled navigation on the lower lakes.

Passenger traffic was quite extensive on the lower lakes in the early fifties. About 1854 a line of splendid paddle-wheel steamers was established on Lake Erie, making express connections between Buffalo and Detroit, and operated in the interests of the New York and Michigan railroads. In later years, when railroad connections had been improved, there was a marked decline in the passenger traffic on the Lakes. This service, however, has much increased during recent years.

The navigation of Lake Superior was of little importance prior to 1856, chiefly owing to the fact that Lake Superior was not connected by a navigable channel to the lower lakes. Boats were then portaged over the Sault Ste. Marie; the smaller vessels were pulled over the rapids and the larger vessels overland. The little traffic that was done was unloaded at the "Soo," carried down the land portage of the river, and re-loaded at Lake Huron.

The subject of making connections between the lakes was very early agitated. Prior to 1850 the matter had been discussed by the State of Michigan,—shortly after it was made a State,—and it had been agitated in Congress for some years, until about 1852 the United

States Government made a land grant for helping to build the first locks at Sault Ste. Marie.

As indicative of how little was appreciated of the possibilities of trade and commerce on Lake Superior, there is a story told of the argument used by Henry Clay when he spoke satirically of the canal scheme as "contemplating a work beyond the remotest settlements in the United States,—if not in the moon." And I am here reminded of another story, told of Daniel Webster, when the methods of improving our connections by way of the Isthmus were being considered, and the question of aiding a route to California was brought up. "Never would he vote a dollar of the public funds for the purpose of bringing the bleak, barren, inhospitable shores of California one step nearer to Boston." And there are many other utterances by prominent men along the same lines.

The subject of transportation, however, was stimulated in the case of Lake Superior by the early discovery of copper, and by the fact that this copper was to be found in great abundance and of good quality. Therefore they kept hammering away on the lock question, and finally succeeded in getting a grant of land from the Government, and the State of Michigan opened the first Ste. Marie locks in 1855.

The fact is not generally known, but it seems that there was an earlier lock on the Canadian side. It is an illustration of the enterprise of that great monopoly the Hudson Bay Company, who, as you are aware, had early settlements along Lake Superior, with headquarters at Fort William at the upper end of the lake. This was a rendezvous for fur traders, and away back in 1790 or 1795, they built a small lock for passing boats past the Ste. Marie rapids. The walls of this lock were built of dressed timbers, and it had a lift of about nine feet; the whole length was about eighteen or nineteen feet, so that for about half the lift the boats were warped up the current, and raised through this little lock.

This was almost forgotten until recent records were found of this old lock. Mr. Clergue, then General Manager of the Consolidated Lake Superior Company, found the records of this old lock, and had it reconstructed as a memento of past history. It is a matter of ancient history, however, and has little bearing on the subject of a lock or canal for passing vessels of magnitude. To those of you who have not been there, I may say, in passing, that the falls of Sault Ste. Marie is a fast-running water-way, a rapid stream which the early French

voyagers called the "Sault," a name given to others rapids by the French. The Ste. Marie River has a fall of 18 or 19 feet in little less than a mile, and was practically unnavigable. There was a permanent settlement of Indians here, and the river was always open. The rapids kept it open. Whitefish were in great abundance in the lakes, and afforded a constant food-supply for the aboriginal inhabitants.

The first locks were opened in 1855, two in number, with a lift of 9 feet each. They were 350 feet long, 70 feet wide, and 11.5 feet deep, the cost being about $1,000,000 for canal and locks.

A letter of Captain Ward's, still in existence, shows how little in those days they appreciated the necessity of having ample water-ways. He wrote to the State Legislature, and to Congress, objecting to the size of the lock. Wanted it smaller; about 250 feet long would be ample, and showing that the obstructed channel of the Ste. Marie River would not take boats longer than this. He was a man of great enterprise, largely interested in the lake traffic; he built the large iron works at Wyandotte, and was instrumental in building the first works at Chicago. It is an illustration of how little we can foresee the necessities of the future.

These locks soon proved inadequate for the growing commerce of the lakes, which was subsequently further increased by the opening up of the great iron mines of Marquette, so that about 1881 it was found necessary to enlarge the locks, and they were replaced by a single lock. The lift was 18 feet, width 80 feet, and depth 16 feet. The total length was 515 feet. At this time the water-way was transferred by the State of Michigan to the United States Government, who took charge of the work in 1896. The second locks were again found to be unequal to the demands of navigation, and a third lock was built. This is 800 feet long, 100 feet wide, and 22 feet deep. It has a single lift of about 18 feet. At about the same time the Canadian Government built the lock on their side of the line. Their lock is 900 feet long, and about 60 feet wide, 22 feet deep, and 18 feet lift.

As a curious illustration of how little can be foreseen of the future, in connection with the 60-foot width of this lock, vessels are now on the lakes that are more than 60 feet wide.

There is now an agitation to still further enlarge this lock. The intention was to pass four vessels at one time through the lock, and then the possibilities of the future began to dawn on them. Vessels now are built over 500 feet long, with carrying capacity of 10,000

tons, and only one can be handled at a time; consequently more lock capacity is demanded. These locks now pass a tonnage of 35,000,000 tons annually—probably a greater tonnage than any similar waterway in the world, being more than double that of Suez.

The principal traffic passing through the locks consists of iron ore, grain, lumber, and coal.

If any particular district of our land possesses *par excellence* a potentiality of mineral wealth beyond the dreams of avarice, it is the region tributary to Lake Superior. The copper deposits of Lake Superior were known to the first French voyageurs, and are supposed to have been worked by prehistoric man in the unknown past. Thus the existence of copper was known on Lake Superior, but not well developed before 1819 or 1820. Then General Cass, of Michigan, explored this region for the United States Government and reported the existence of large deposits of copper, but no mention was made of iron ore. The first definite information was obtained about 1840, when Dr. Houghton, the State Geologist, made a definite exploration and made some positive assertions in regard to the value and extent of the copper deposits, but apparently had no knowledge of the ores of iron.

John Hayes, of Cleveland, is accredited as the first successful worker of copper ores, and between 1845 and 1850 he laid the foundations of this great industry.

I well remember, back in 1856 when a boy in Michigan, hearing my friends talk of speculations in "copper," and the question was then whether one could safely invest in copper stocks and mines. Among the principal stocks discussed at that time were Calumet and Hecla, a company started in Boston for the purpose of operating in copper; the stock was at a very low price, and was the subject of considerable speculation. Within the past fifty years this corporation has paid about $75,000,000 dollars in dividends, and the stock is now worth forty or fifty fold its original capitalization.

About 1844 or 1845 a Mr. Burt, a United States surveyor, was engaged in making surveys on the Michigan shores of Lake Superior. Burt on one of his surveys noticed extraordinary deviations in the compass when going over certain ground; that told the man there was something unusual there. A little investigation showed the outcropping of large quantities of iron ore back of Marquette, and he reported this find, but no further work was done until about 1849 or 1850, when the first ore was uncovered and worked in a small way until the canal was opened in 1855.

That year about 1500 tons of ore were transported through the locks. The product of this year is about 33,000,000 gross tons. In all, nearly 300,000,000 tons have been taken from the Superior mines. I refer to the five great ranges in Michigan and Minnesota. This iron district supplies now nearly one-half of all the product used in the blast furnaces of this country. Previous to the Civil War cargoes of the lake ores were infrequent, and in the early days the methods of handling were very crude; most of it was shoveled into wheelbarrows and loaded on scows. I recall that it was a very rare thing to find steamers carrying ore; they did not want to bother with it, and so it was relegated to sailing sloops and scows. Now there are lines of steamers that make a business of carrying iron ore alone. Some of them carry 10,000 tons burthen. With the improved grab-bucket system now in use, large cargoes are handled in little time, and each bucket will handle about 500 tons of ore an hour. Any of you who have had an opportunity to observe these appliances can bear witness to the marvelous and economical methods of handling ore in practice today. The Lake Superior ore became very valuable, not only on account of the magnitude of the deposits, but on account of its rich quality; the analysis shows an average of 65 per cent. in iron. There is always a great demand for Bessemer ore, and these ores were especially adapted for it, being usually low in phosphorus and sulphur, and thus well adapted for the Bessemer process.

The great deposit of ore discovered about fifteen years ago at the Mesabi range is probably the most extensive deposit of iron ore in the world that we know of. It is also handled at little expense by steam shovels, being very largely in granular form. Up to 1904 the Mesabi range has yielded about 80 millions of tons, the Marquette about 75 million tons, the Menominee 50 millions, the Gogebic 45 millions, and the Vermillion range about 25 millions of tons; or, in all, about 300 million tons of ore up to date, so that we can understand the necessity and importance of having the very best waterways and connections that can be furnished at Sault Ste. Marie.

In addition to these deposits on the Michigan, Wisconsin, and Minnesota side, you will remember that extensive deposits have been discovered in Canada. It is probable that the northern shores of Lake Superior will also prove to be valuable. When the Consolidated Lake Superior Company built their works at the "Soo," large deposits of ore were discovered on which they are working,

and which are now proving to be valuable, so that the end is not yet in sight, and the full development of the iron ore product of the Lake Superior territory is still in the future.

At this time the West was being rapidly populated; the State of Illinois especially was very quickly settled. Illinois was settled quickly for several reasons. In the first place its railroads were built cheaply, the land being comparatively level, few extensive rivers to bridge, it was a comparatively inexpensive matter to ship rails, it was easy of access for travelers over the Great Lakes, and in line with the railroad extension toward the West. Therefore it had a very rapid development and led the way to open up the wheat fields of Minnesota and the granaries of Nebraska, districts that were practically non-existent at that time.

During the period preceding the financial panic of 1857 the railroad system had extended pretty well over Iowa and to the center of Wisconsin, but little further, and there was no way of reaching Lake Superior in the winter season except on snow-shoes, sleds, etc. In 1857 a representative of the legislature from the upper peninsula of Michigan tells how he spent three weeks traveling to Fond du Lac and thence across Lake Michigan to the capital. The Superior mails were then principally carried from Fond du Lac or Oshkosh, and were transported largely by Indian carriers. The mails were principally handled from the Wisconsin side, so as to avoid crossing the lake.

At this time comparatively few food products were transported to the East as they are now. The modern systems of railroad transportation had not been completed, and freight rates were very high. About the outbreak of the Civil War the rates between Chicago and New York on corn and wheat were about 50 cents a bushel; now the rate is about 9 cents, all rail, or 6½ cents lake and rail. When he had large crops, it was a question with the farmer what to do with his products, and corn was used occasionally for fuel, and sometimes sold as low as 8 or 10 cents a bushel. It was cheaper to burn it than transport it, and a great deal was fed to hogs, who transported themselves. Cattle and swine were transported alive, and it was a common occurrence to see immense droves of hogs traveling overland through Ohio and Michigan to the lake ports and thence by water to the Eastern markets. These animals traveled this way for considerable distances, several wagons following the rear picking up weakened stragglers.

The Western farmers then were largely a debtor class; their farms were usually mortgaged and rates of interest were high—8 or 10 per cent. Hard drudgery and unceasing labor were allotted to the farmer, but industry and enterprise stimulated inventive talents, and these sturdy yeomen were the first to adopt the modern agricultural implements.

When considering the great development of mines and manufactures, we must not forget how these interests, in magnitude and value, dwindle to insignificance beside the immense agricultural interests of the country, which are now estimated to have a value approximating $7,000,000,000 per annum.

The annual product of food grains now aggregates about 4,000,000,000 bushels. It is asserted that the value of hens' eggs alone runs close to that of all the ores of metals produced in the country. Approximately one-half of our population are engaged in agricultural industry or the sale of the product. Fertility of land or industry of the farmer alone would not suffice to create existing conditions. The most important requirement is economical means of transportation, to render practicable the distribution of these immense products over the greatest possible area.

For internal distribution the railroad is our chief dependence. Before the era of railroads it was possible to have superabundance in one district and famine in another contiguous to it, as described by Macauley, in his description of the seventeenth century in England. It is therefore the part of wise statesmanship to foster the railroad systems in every way that will best conduce to the needs of the country.

The type of Mississippi steamboat of that time has changed but little since, and it seems probable that there were finer boats then than now. They were capacious and comfortable to travel on, and offered attractive inducements to the traveler. The type of boat was similar to those in use now—usually the well-known stern-wheeler, with the single paddle-wheel hung on the stern of the boat, operated by long-stroke engines, with poppet valves, operated by side-levers. The engines were in pairs coupled at right angles to the paddle-shaft. The standard boiler had a long shell with twin flues and return draught, and high chimneys guyed to the hull of the boat. The type has changed little within fifty years.

A peculiar feature was that this was the only part of the world at that time where high-pressure steam was carried. Pressures of 100 to 120 pounds were common and usual. Operators were noted for

their recklessness and many engineers were of the Jim Bludso type, who loaded their boilers to excess, and the boilers themselves had a peculiar habit of leaving the boats occasionally without much warning and heaving the passengers into the river.

Nicholas Roosevelt, who built the first pumping engine for the Philadelphia waterworks, is credited with having installed the machinery in the first steamboat launched at Pittsburgh, and probably the first on the western rivers. He was evidently one of the pioneer machinists of the country.

At that time, traffic on the Mississippi and its eastern tributaries was quite extensive. The river formed the principal avenue for communication between the northern and southern Middle States. The great products of the Pittsburgh region depended on the river for an outlet. My earliest recollections of Pittsburgh, Cincinnati, and St. Louis were of continuous lines of steamboats crowding the levees, usually laden with freight and passengers to their utmost capacity. Altogether it was a vivid, exciting, and attractive life to the adventurous spirits of the time. General recklessness of life and property was frequently too manifest for the comfort of the timid, and the presence and outfit of the gambler, backed up by bowie-knife and revolver, were not reassuring to the non-combatant of peaceful habits. The Civil War resulted in a reduction of this river traffic, and railroad extension has prevented its resumption on the old scale.

The railroads of that day were built as cheaply as possible, and generally in advance of the immediate needs; they were built for the population to follow the roads. The type of road, of the locomotive, and of the rolling stock had been pretty well settled several years before. The outside connected engine, with slide valves of long stroke, was standard, in general design similar to, but smaller than, those of the present time. There was still built an inside connected engine, since abandoned here, and instead of the link motion for reversing, drop hooks on the eccentric rods were used to some extent. The roads themselves were roughly and cheaply constructed; rails of 40- to 50-pound pattern were usual.

I cannot recall the splice bar on the rails of the western roads. The joints were supported on chairs with curved lips which grasped the lower rail flange, the chair rigidly spiked to the cross-ties. The passenger could form some conception of the train speed by observing the click of the joints. Sleeping-cars were not in use. The first sleeper I saw was in the winter of 1858–59, between St. Louis and Cin-

cinnati. The gauge question was still debatable, but it was about definitely settled what the proper gauge should be. Several important lines were laid with six-foot gauge; the Erie Road was 6 feet, also the Ohio & Mississippi between Cincinnati and St. Louis, now part of the B. & O. system. Subsequently these roads were changed to the present gauge.

Speaking of gauge brings to mind the "battle of the gauges," a controversy strenuously urged in England in the decade previous to the one under review. Brunel and Stephenson, the foremost engineers of the time, were the special advocates respectively of the wide and narrow gauges. The one, an advocate of great work, showy and monumental; the other, of construction, successful from a commercial point of view, and that would pay.

Brunel was consulted in the interests of a new line, and in response to the question of gauge, said: "Of course, I usually, on general principles, advise the wide gauge; but bearing in mind your particular case as described to me, I would recommend the narrow gauge."

Stephenson was also consulted, who responded: "For all ordinary constructions I advise the narrow gauge, but in the case under discussion, the possibilities of large traffic are so obvious, and the needs of preparing for it liberally are so manifest, that I would advise the wide gauge."

The bridges of those days in the West were all wood. There were isolated cases in the East of iron bridges, and Stephenson and Brunel in Britain had built some novel types of iron bridges. Nevertheless the great bridges of the country were wooden structures, and the standard bridge of the time was the Howe truss. These structures were rarely over 150 feet span—which was nearly the limit—although there were a few examples of not very satisfactory 250-foot spans. The Howe truss bridge was composed of parallel timbers, usually of white pine, in which the top and lower chords were composed of the same number of timbers of the same thickness, with the lower a little deeper than the top chords, to allow for the transverse strain. The web tension members were vertical iron rods, the wooden main braces and counter-braces were inclined and abutted against cast-iron skew blocks. I believe that Howe's patent was based simply on the use of these cast-iron skew blocks. The chord timbers were generally separated about two inches, for ventilation, and were usually spliced with hard wood. The splices were staggered to avoid more than one joint in one panel.

The experience with all wooden bridges was that when uncovered their life was comparatively short, rarely exceeding ten years; but when properly covered, keeping moisture out of the joints, much greater permanence is assured. I believe there are some wooden Howe trusses extant that have lived over forty years. Squire Whipple had built a number of highway iron bridges prior to this time and several weak and imperfect iron bridges had been built and condemned on the Erie road and others, but the use of iron bridges cannot be said to have been satisfactorily established until the close of the Civil War.

Iron Manufacture.

Mining and the manufacture of iron were carried on to a considerable extent in the State of Missouri at this time. Owing to the large deposits of ore there, and the facilities for water transportation, this industry was begun in a primitive way early in the century. Charcoal was the only fuel used; indeed in 1856 about one-half of the pig-iron product of the country was produced with charcoal, and nearly the other half from anthracite in eastern Pennsylvania. Coke was but little used at this time, nor raw bituminous coal in the blast furnace; in 1856 only about 10 per cent. of the total pig-iron product being due to these latter fuels. The manufacture by anthracite was well established, and the large furnaces of the Lehigh district were then being constructed. Hot blast was rarely if it all used at charcoal furnaces, and only the iron pipe stove at anthracite furnaces, the regenerative hot blast coming at a much later date. All blast furnaces of the period were heavy square masonry structures, and all worked with open tops.

The iron casing or cupola type furnace, and the bell and hopper, were all adopted in subsequent years. The ordinary charcoal furnace of Missouri, as I remember it, was a crudely built mass of masonry, about twenty feet high, with a bosh diameter of about eight feet and hearth about two feet square. These furnaces produced four or five tons of pig metal per day, and consumed about two tons of charcoal per ton of metal produced. The old charcoal furnaces of the country when practicable were located against a hillside, for facilitating charging on top and drawing the product below. Water-power was used where available, but as this was usually an uncertain dependence, the tendency of the time was to use steam-power. The blowing engines were simple and crude; the blast cylinders or tubs, as they

were called, being frequently built up of wood. But even the great anthracite furnaces of the Lehigh, in the late fifties, had only about one-fourth of the productive capacity of furnaces today. But the iron manufacture has advanced by leaps and bounds, and the output of pig-iron has increased over twenty-five fold within the half-century. If it should continue to increase in a similar ratio, it is a serious question where the ore supply will come from.

A peculiar feature of the iron industry in Missouri at that time was the long distance this material was transported by road wagons to market. It was a common occurrence to see wagons with several yoke of oxen hauling pig-iron to the nearest point on the river or railroad for transportation to St. Louis. How far it was actually carried I do not know, but I recollect cases of over thirty miles, and in the early days possibly much further. At times a river ford would be impassable on account of high water, and they would then unyoke the oxen and wait until the water fell. This seems an exceedingly primitive method of transportation, but we are told that similar methods were in vogue in New Jersey and Pennsylvania in the early part of the century.

The years 1855–57 showed marked development in the production of iron. In these years Captain Ward built the furnaces and rolling mill at Wyandotte for working Lake ores; also a mill at Chicago for re-rolling rails. This latter was the original of the North Chicago works of the Illinois Steel Company. The works at Wyandotte, below Detroit, were considered a great advance for the time, and at those works in 1864 was produced the first Bessemer steel made in this country. The rolling mill was in a crude state as compared to existing mills. The boiling process had practically superseded the older method of dry puddling, and the rotary squeezer was being introduced, but its predecessor, the alligator squeezer, was still in common use. Rails and similar bars were rolled in two-high mills. In 1857 Mr. Fritz put in the first three-high rail mill at Johnstown, but it was several years later before the mill was generally introduced.

Even as late as 1868 A. L. Holley read a paper on American three-high mills before the British Iron and Steel Institute, and from the statements elicited it would appear that three-high rail mills were not used in England at that time.

Primitive charcoal bloomeries were scattered over the country, and direct processes of making malleable iron from the ore, in forges of the Catalan and similar types, were not uncommon. These and

many other primitive methods then extant have now become obsolete.

The introduction of Bessemer and open-hearth steel crystallized the industry into standard methods of production on large and economical scales, which effectually prohibited the older methods.

Hydraulic cement was but little used during the "fifties" and Portland cement was unknown here. It is true that the natural cements of Rosendale, also of Virginia and Kentucky, antedated this, but freight rates would not permit of their distribution to long distances from the point of manufacture and the total product was about half a million barrels in 1856. It was twenty years later before the industry became securely established. Since then the use of cement has become nearly universal, a production now of about 30,000,000 barrels annually being attained.

Ship- and Boat-building of the Time.

At the period prior to the Civil War the ship- and boat-building trade on the ocean front and on the Great Lakes was an important industry, and the clang of the caulkers' tools was a familar sound. Prior to the Civil War it is asserted that if the tonnage of the world had been divided into three parts, the proportion would have been one-third to Great Britain, one-third to the United States, and the remaining third to the rest of the world, showing that this country had been making rapid strides in ship-building. This industry subsequently declined, for several reasons. Commercial shipping was either destroyed or embarrassed during the war. Iron was superseding wood for ships' hulls, and iron advanced to a high price during the war. The economical policy of the country favored internal development, to the disadvantage of foreign trade. All these conditions were factors operating against American shipping, which has never since resumed its former proportion. The great ocean liners of today are largely built and owned in Britain and Germany.

The compound engine, although well known, was not used prior to our Civil War. The steam pressures then rarely exceeded 30 pounds on ships. During later years high-pressure steam was employed, and the adoption of the multi-cylinder expansion engine followed as a natural sequence.

There are reasons to believe and it is to be hoped that the ship-building industry will take its proper place, in the near future, as an important department of American enterprise.

Those whose memory does not antedate our national currency can form little conception of the loss and confusion pertaining to the old State bank issues, especially in the West. The rapid development of the country created a great demand for money, and there was little accumulated wealth in the shape of fixed capital. Unusual facilities were offered by the individual States for the establishment of banks, which were too frequently founded on insufficient security. The country was flooded with counterfeits and the paper of insolvent banks. Every business man kept the last issue of the bank-note detector at hand, and consulted it for description of the latest counterfeits or bank failures.

The issues of one State were not freely current in another, and brokers did a thriving business in discounting uncurrent notes. Probably no greater benefit was ever conferred on the country than the establishment of the national bank system, with its unquestionable security, and the abolition of the unsound State bank currency. The production of California gold in the early fifties effected a great relief and improvement in metallic currency over the conditions of previous years, but much defaced and worn coin was in circulation on the Mississippi borders. Mexican coins were abundant and there was no dearth of spurious coins.

The great discoveries of silver in Colorado came at a subsequent period, resulting in the severance of its long-standing ratio of value to gold, and engendering the strenuous "silver question" of the last decade. The modern leaching systems for the separation of gold were then unknown, which has resulted in a vast increase of gold production in recent years, threatening a disturbance in values which may prove a serious and vital question, if gold production continues to increase at the ratios of the past few years. The world's production of gold now amounts to nearly $400,000,000 annually. It has more than doubled during the past ten years. This great increase is largely due to the adoption of the cyanide process.

In those days technical education as a special system of instruction hardly existed. The Rensselaer Institute, at Troy, was the only school of engineering of any note in the country. A translation of Weisbach's "Mechanics" had appeared and made a great impress as the beginning of the modern science of applied mechanics. Rankine's admirable works were then being written, and served a beneficent purpose in later years. But the common schools of the day were doing good work, and more attention was given to mathematics

and the physical sciences than is customary today in schools of a similar class. The lyceum and public lecture systems were in full swing, and were well attended. Courses of popular lectures on the sciences and arts were apparently more frequent and received more attention than in later years.

Accumulations coming through patient industry and earnest endeavor are more thoroughly appreciated and more carefully guarded than when obtained in an easier way, and notwithstanding the great advances of the era, which has stimulated human production beyond the most sanguine anticipations, it is still questionable if the masses of the people are more prosperous or life more cheerful than in the happy days of long ago.

Francis Schumann.—I do not intend any formal address this evening; I can only speak of my recollections, which cover about the same period mentioned in the very interesting discourse of Mr. Christie.

It occurred to me while listening to Mr. Christie that a very proper question to ask would be, how and where did the civil and the mechanical engineer of fifty years ago acquire his technical education?

Rensselaer was, I think, the only polytechnic college in our country, though we had private tutors for drawing, mathematics, mechanics, and statics. For text-books we had Barlow, Tredgold and Farey on the steam-engine. On structure there were Fairbairn and Hodgkinson, with Willis, Holzapffel and Buchanan on machines, and Hood on heating. The handbooks were those of Haswell and Nystrom.

The literature of the period on civil engineering was very limited, although Brown, Burr, Fink, Bollman and Roebling were active as scientific bridge-builders.

While Mr. Haupt had at that time published analytical methods for determining strains in bridge trusses, nevertheless the knowledge of statics was limited and the "rule of thumb" was used, and like the mechanical engineer who was preceded by the millwright, the civil engineer in bridges and truss design succeeded the practical bridge framer, who possessed certain graphical methods of his own in determining the proportions of members of a structure.

Close observation and practical application were paramount in acquiring our training.

Just a word regarding the currency of that period. My memory goes back to a trip from the middle of Iowa, through Ohio, Illinois,

across the Ohio River to Richmond, Va. I escorted my mother, who had with great trouble collected several hundred dollars in paper money, supposedly current in the States through which we would pass. It happened that during the time of the trip in Ohio, changes had occurred in the currency to such an extent that none of our money was accepted when we got to Piedmont on the Ohio River, nor would it pass in Virginia, across the river. By great effort and appeal we induced a storekeeper to exchange sufficient negotiable notes for ours at a big discount, this allowing us to proceed on our journey.

At Richmond I was shown through one of the machine shops, and the first thing that impressed me was a beautifully designed and finished oscillating steam-engine of about fifty horse-power, operating a machine shop. In another department was a stationary engine of ten inches bore and forty-eight inches stroke, with a ten-foot fly-wheel. This engine ran at fifty revolutions per minute with a steam-pressure of between thirty-five and fifty pounds.

Much larger engines than these were built at this time, using rotary poppet or sliding valves. I mention the above examples to show how indefinite were the opinions as to style, design, and proportions.

Progress or advances made in one State or locality spread slowly, through lack of current technical literature or intercourse between engineers. It was the custom fifty years ago for many foundries to make coke for cupola purposes. Every good foundry had, in addition to cupolas, air furnaces, and this fact will probably explain the excellence of the castings made during this period. Scotch iron was used extensively, with a large proportion of domestic charcoal iron.

The draughtsman in machine shops was often a practical mechanic, either a pattern-maker or a machinist. Elaborate drawings with much brush shading were in vogue. Shop drawings were made full size on poplar wood boards about one-half inch in thickness, the surfaces planed, sandpapered and then whitened. Upon this surface the details were drawn, and the whole finally covered with a coat of shellac varnish.

Many of the machine tools of the day had been imported from England; the use of the hand tool was much cultivated and remarkable skill was shown, screw threads especially being cut with great accuracy. The chisel was a most important tool for dressing surfaces and cutting key-ways.

It was then still the custom for machine shops to make all pipe and brass fittings used in the work. About this time Mr. Robert Briggs

had determined the proportions of pipe fittings, his findings being first published, I believe, by Morris, Tasker & Co. These proportions are still adhered to.

The wages paid half a century ago were much lower than those of today.

Helpers in foundries and machine shops received from $5 to $7 per week, journeymen from $8 to $10 per week, while machine shop foremen received from $11 to $12. Pig-iron cost about $26 per ton, while as much as 7 cents per pound was paid for gear-wheel castings of several hundred pounds' weight.

High buildings existed even at that time. The Galego Mills at Richmond, Va., were brick structures 13 stories high, while the foundations were, I think, 21 feet thick.

The twenty years between 1856 and 1876 bridge the gap between old-time and modern engineering methods. The advances and the enormous changes during the period are almost incomprehensible. Especially so when one considers the short space of time in which so much progress has taken place.

John M. Hartman.—When I was a small boy, going up the Brandywine Creek of Chester County, Pa., there were numerous charcoal forges with their sinking fire making about 500 pounds per day. The thump of their trip-hammers could be heard a mile away.

Further up the country was the old Warwick cold-blast charcoal furnace, famous for the cannon made during the Revolution of 1776. It was a square stone stack about 30 feet each way, 30 feet high, built against a bank. These furnaces had one tuyere. The nozle was tin pipe, and blast was conducted through it by a large leather hose. The nozle was laid on a board in front of the tuyere, leaving an annular space between the tuyere and nozle to draw in more air. The nozle was pushed forward when more penetration of blast was wanted.

The top of the stack was on a level line with the top of the bank, which was used as a stock-house. The ironmaster built his furnace on a creek to get power to run the wooden blowing tubes for the blast. These old wooden tubes could be heard screeching and groaning a long distance off. The ores were mostly magnetite with a little sulphur. They were roasted and broken up the size of a shellbark, and yielded not over 50 per cent. iron.

Wooden barrows were used to fill the furnace. Two and one-half tons of charcoal were used to a ton of iron, and 20 to 25 tons of iron

were made per week when running well, which was considered good work. Today 700 tons per week are made in charcoal furnaces.

On the French Creek were forges also, one of which was two miles above Phœnixville.

A Welshman and his wife built this forge and dam. The husband ran the forge by night and the wife by day. She was as good a hammerman as her husband and sat astraddle of the billet handle while forging the billet. They died well-to-do.

The charcoal was burned in meilers on the hillsides, often ten miles from where it was used. How the drivers hauling the charcoal to the furnace could find their way to the meilers through an unbroken country with no roads was a wonder.

William Firmstone, the father of our coke pig-iron, died a few years ago at Easton, Pa. He made the first coke pig in 1835 in a charcoal furnace. He was a strong advocate of hot blast and was the first to apply it to coke furnaces. They made from 50 to 90 tons per week. Today, with our large furnaces and firebrick stoves using coke and Lake Superior ore, we make 3800 tons per week in one furnace.

David Thomas is known as the father of anthracite pig-iron, as he built one of the first anthracite furnaces, in 1839. The great difficulty with anthracite was to get it to burn. David Thomas sat on the furnace bank and shed tears at some of his failures, but by heating the blast and using more powerful blowing engines he finally established the pig-iron industry.

Fifty years ago the produce of a furnace on anthracite was 150 tons. I well remember when the old furnaces at Andover got up to 275 tons a week, which was regarded as a miracle.

Today all anthracite furnaces use some coke to ease up on the blast pressure. The output is about 1600 tons per week with the lean ore we get, mixed with some Lake Superior ores.

Fifty years ago there was nothing but the wagon or canal to transport material. All iron-works kept their stores, in which the workmen dealt, but the workman rarely kept out of debt to the store.

Today looking over the ruins of the old iron-works we are reminded of the struggles they made and the difficulties they overcame with their small, cheap furnaces.

PAPER NO. 1018.

THE TELEPHONE SYSTEM OF TODAY.

C. J. H. WOODBURY.

Read February 5, 1906.

THE remarkable development of electricity applied to the service of man for illumination, conveyance of power, and transmission of speech, during the ten years following the Exposition in 1876, at Philadelphia, is an illustration of the aphorism that "progress always advances by leaps," and was probably without parallel in human history excepting the development of Grecian art in twelve years from a condition of mediocrity to the Golden Age of Phidias.

It is always pleasant to record improvements and advances in any state or condition. The trite phrase that "electricity is in its infancy" is a time-honored one, having been used in 1792 by George Adams, philosopher and optician to His Majesty George the Third, in "An Essay on electricity Explaining the Principles of that useful Science," in which he states, on page 35, "As electricity is in its infancy when considered as a science, its definitions and axioms cannot be stated with geometric accuracy."

EARLY ATTEMPTS AT TRANSMISSION OF SOUND.

The endeavor to communicate sounds by vibrations is not a new one, the string telephone being described by Dr. Robert Hooke, in his book on "Outacousticons," in 1667. Over a century earlier the transmission of vibrations to a diaphragm was applied during the second siege of Rhodes, in September, 1552, as related in the "History of the Knights of Malta,"* by Major Whitworth Porter.

In this siege the Turks sank shafts and drove galleries beneath the principal bastions. Gabriel Martingo, a Venetian engineer in charge of the fortifications, excavated pits into which he inserted long rods, against the upper ends of which he placed a drum, and the vibrations of the earth in the tunnels made by the Turks were transmitted to this drumhead, which enabled the Knights to determine their location

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* Longman, Brown, Green, Longmans & Roberts, London, 1858, vol. i, page 453.

and to sink countermines and destroy the advance of the enemy in this manner.

As an example of the wish to extend the limits of speech, by means of electricity, reference is made to "Harper's Magazine," for June, 1867, where it is related, on page 131, that after a telegraph office was burned, an instrument was temporarily installed in a carpenter's shop. One noon the instrument clicked vigorously, and the carpenter placed his lips to the instrument and shouted, "Operator's gone to dinner; be back in half an hour," meantime receiving a shock in his lips which served for remembrance.

This man had the desire, thought, and conception in his endeavor to apply electrical apparatus to the transmission of speech, but he did not accomplish his purpose and failed to produce an invention.

There is nothing new in the conception that eventually something would be produced to add materially to the range of the human voice, but invention is a practical result in the victorious solution of a new problem and is not a futile attempt or a passing wish.

Humanity has always desired to add to the potentiality of the voice, by attempts to extend the range of utterance, but the masks of the Grecian actors, speaking tubes, and stringed diaphragms were of as little purpose as signal fires, tom-tom beats and semaphores, and the full measure of the strength of the invention of Alexander Graham Bell is shown by the fact that the telephone stands as the only successful result after centuries of effort.

The Telephone Instrument.

When one removes the telephone from its hook and presently holds conversation with another person in the same building or in a distant city, there is set up a train of action possible only under the concurrent action of science and handicraft, labor and capital.

It may be worth while to trace some of these steps and the results to which they are tending in modifying methods of life in business and personal affairs.

The telephone system ministers to the needs of civilization in lengthening the potent life of mankind by the utilization of time.

Your consideration is asked for the telephone system, rather than for the telephone as an instrument, an invention which is the most delicate piece of philosophic apparatus yet made by man, in that it is operated by less energy than any other contrivance.

It transmits in miniature the infinitesimal overtones which indi-

cate the character of sounds, the individual quality of a voice or the source of a tone, through the whole range of vibrations far beyond the limits of the human ear.

Yet as an essential portion of the general subject, something should be stated relative to the methods of its operation.

The telephone differs from all other electrical devices in that it is the only electrical appliance which does not require skill on the part of its users. It is equally the servant of all; a polyglot, it speaks all languages and acts as a faithful messenger for the whole gamut of sounds.

While this device is of the utmost simplicity in its construction, yet the phenomena of its operation are based on a complexity of principles, some of which can be explained only on the basis of a hypothetical framework.

The action of the telephone is based upon two fundamental principles.

First, the relations of electricity and magnetism are of such reciprocal nature that if a closed coil of insulated wire is wound around a magnet, variations of magnetic strength produce corresponding undulations of electricity in the wire, and the apparatus is to this extent a generator of electricity; and, conversely, if the electric current traversing such a coil is varied, the attractive power of the magnet is changed in like manner.

Second, the attractive power of a magnet varies with the distance of the armature from its poles.

When a pair of telephones are connected together, the ends of the line wires are attached to the terminals of the coils surrounding the poles of the magnets in the telephones, and when the sonorous vibrations of the voice are directed against the soft sheet-iron diaphragm of the telephone, its vibrations produce corresponding undulations in the strength of the magnet, and this in turn generates variable electric currents in the coil wound around the magnet, and thence throughout the whole electric circuit of which the coil at the other telephone forms a portion, and at this other telephone the undulations of electricity produce like changes in the strength of the magnet whose varying power causes the diaphragm to vibrate in unison with that of the first telephone, and to give forth in miniature a repetition of the sounds which were imparted to the first telephone.

Telephones were formerly used in this manner without a battery, and while the transmission was clear even to distances of 500 miles,

yet the sound was "as weak as the voice of a seared conscience," and hardly equal to the commercial requirements of public service, particularly amid the rumble of cities, and could be used only where there was absolute quietude.

The telephone is no exception to the general experience of the retrospective simplicity of a great invention, and while its operation has been described, no one has yet been able to explain why the telephone talks.

Even if the diaphragm is removed from a telephone the magnet and coil of wire remaining will give forth speech whose vibrations it receives; also a condenser, even when crudely made by inserting sheets of tin-foil between the pages of a pamphlet, will produce sounds in like manner.

While the telephone was an invention of radical novelty, made without the assistance of precedents to govern its assemblage, yet its degree of perfection is such that it has escaped improvement, and is today in its entirety as produced by Dr. Alexander Graham Bell.

The Transmitter.

The former method of using a pair of telephones transmitted speech with the utmost clearness, but of such minute volume as to be inadequate for satisfactory service amid disturbing noises or for long distances, and the transmitter was invented for the purpose of producing greater variation in the undulations of an electric current applied to the telephone circuit than could be done by the application of magnetism in the telephone.

This result is accomplished by applying electricity from a battery, and changing the conductivity of this circuit in unison with the vibrations of sounds imposed upon a diaphragm, without the intervention of magnetism to produce such variations in the current.

The general purpose of the transmitter may be compared to a method of varying the flow of water conveyed through a soft rubber tube by intermittently constricting its diameter by applying changing pressures upon it at some portion of its length.

Its electrical principle is based upon the fact, well known to every telegraph operator, that the contact of a telegraph key with a well-defined pressure is necessary to obtain a satisfactory flow of current through its connections; and the transmitter in general use applies this principle in a more delicate manner, by using a number of loose particles of material whose conductivity is improved by pressure which increases the points of contact.

Each end of the telephone circuit is attached to one of a pair of discs of carbon, between which are a large number of granules of hard carbon, and as the pressure upon these carbon discs is increased, the conductivity of the circuit and the flow of electricity is augmented accordingly.

In the transmitter, the center of a flexible diaphragm presses slightly upon one of the carbon discs, and the fluttering of this diaphragm alters the pressure upon the carbon granules, and, therefore, their conductivity in the electrical circuit of which they form a portion.

This variable electrical current is conveyed by the telephone line to the coil of wire already described in the telephone used as a receiver, and through its influence the changing strength of the magnet is varied more than could be done by the original method of using a telephone to transmit speech.

There are many variations in the form of transmitters, and in fact every loose or variable electrical connection may in the light of the present state of the art of telephony be made to serve as a transmitter.

Piles of nails, boxes of coke, watch-chains, metal turnings or filings, toy balloons covered with powdered plumbago, coils of wire, plumb bobs touching a surface of mercury, streams of conducting solutions, and arc lights have served such purposes by way of experiment, while in place of the thin iron diaphragms, boiler heads an inch thick, iron plates two inches thick, the side of a frame house, and even that of an iron steamship have been used as diaphragms.

It appears incomprehensible that such rigid bodies should flutter at the sound of a human voice to an extent which would permit them to convert such vibrations into electrical undulations which form the initiative of the electrical transmission of speech, and the only explanation of such experiments is that molecular vibrations are important elements in the unexplained phenomena of telephony.

The brief outline of some of the elements of the telephone and the transmitter should not induce one to overlook the fact that intense scientific research and able mechanical skill were necessary to develop these instruments to an efficiency which has enabled the transmission of speech without skilled usage even up to distances reaching nearly two thousand miles.

Administration of the Telephone System.

The telephone would have remained a piece of physical apparatus, an example of the correlation of forces, an instrument to aid in the

study of sound, and a wonder to all, had it not been for the production of the switchboard, and particularly of the Blake Transmitter, which saved the situation in the development of the telephone system.

It was indeed fortunate for the world's work that the organization of the telephone system from its inception was in the hands of leaders equal to the task of concentrating the labors of many persons upon the sole purpose of furnishing practical operative conditions for the transmission of speech as a public service enterprise.

Its first president, Col. William H. Forbes, was endowed with wisdom to plan and vigor to execute these duties, in the spirit of imagination to foresee future possibilities, combined with a knowledge of present events which he shaped to existing conditions.

To John E. Hudson, an eminent member of the bar, were largely due the measures which established the system in its strong legal position, and to him also is due in large measure its development as a great national enterprise.

The present executive of the American Telephone and Telegraph Company, Frederick P. Fish, was for many years its counsel in the complex causes of patent litigation, and it has been under his administration that the recent growth of the telephone system has surpassed that of earlier years.

The work of these men has been executed by faithful lieutenants from the greatest unto the least in this army of seventy-five thousand unseen toilers.

The Telephone Circuit.

Before tracing the operation of the events set in action by the removal of the telephone from the hook, let us follow the lines from the instrument to the switchboard in the latest type of the telephone system.

Protectors against Foreign Currents.

On the way from the subscriber's instrument if any portion of the wires are aërial, protectors are inserted in the line for the purpose of maintaining the service and defending the instrument against other electric currents imposed upon it by possible contact between telephone wires and those of electric lighting or power circuits or even lightning, any of which would disarrange the delicate wires in a telephone, some of which are so fine that three and nine-tenths miles would weigh only a pound, and these protectors are so sensitive that they

would shut from the telephone the battery currents used in telegraphing; and in like purpose the other ends of the lines at the telephone central stations are equipped with protectors to exclude the whole range of electric currents applied for lighting, power, the numerous signaling systems, and also lightning.

The form of apparatus used by the Bell Telephone Companies, which are especially careful in this regard, consists of a device inserted in each line wire which is threefold in its nature.

The first element consists of a fuse made of an alloy which forms part of the circuit, and is contained in a tube of vulcanized fiber.

These fuses will deflagrate when exposed to currents of seven to ten amperes, the capacity of the fuse being varied according to the type of the apparatus.

The next element consists of a pair of small blocks of carbon whose larger surface measures about one by one-half inch, and one of these blocks is connected to the telephone circuit. The corresponding block of the pair of carbons is separated from it by a perforated sheet of mica and is electrically connected with the earth. A small cavity in one of the opposite faces of the carbon is filled with a button of solder such as is used in automatic sprinklers, and which melts at 160° Fahrenheit.

The distance between these carbons is such that electricity at over three hundred and fifty volts will pass from the carbon connected with the telephone circuit across this space to the opposite carbon and thence to the earth, thereby relieving the telephonic apparatus of electric tension exceeding three hundred and fifty volts.

Thus, if the foreign current exceeds the carrying capacity of the tubular fuse, its deflagration opens the circuit at that point. If, however, it is less in volume than the carrying capacity of the fuse, and over three hundred and fifty volts tension, it leaps across the thin space separating the carbons, and thence passes to earth. The resistance of the tiny arc in the space between the carbons is sufficient to slightly warm the carbons and cause the fusible metal to flow from its recess and fill the space between the carbons and thus establishes a conductor of low resistance to earth.

This diminished resistance generally causes a sufficient increase in the current imposed upon a line to cause the tubular fuse to deflagrate and open the circuit, if it did not do so on the first occurrence of the contact which imposed the foreign current on the telephone circuit.

In order to protect the fine wires of the telephonic apparatus from injury by currents which are too small to operate the tubular fuse, and of too low tension to pass to earth through the carbon cutouts, a third element, known as the heat coil, is employed, in which a fine German-silver wire which forms a part of the telephone circuit will be heated by a current of one-sixth of an ampere to a temperature sufficient to release a conductor ordinarily secured by fusible solder, and pass the current to earth. This latter device is not used at the subscriber's end of the line in those modern types of telephonic apparatus in which the circuit is normally open, except when the telephone is in use, because such coils are an interference with the best conditions of telephone service by adding to the electrical length of the line, and if a foreign current came in contact with the telephone line at a time when the instrument was in use, it would produce noises to such an extent as to absolutely prevent the transmission of speech, and the user of the telephone would naturally place the receiver on the hook and thereby open the circuit.

The result of this protective apparatus has been so successful as to establish conditions of immunity in the Bell system of telephony against mishaps to the apparatus resulting from foreign currents and lightning after an experience of many years throughout the Bell Telephone system. Such a telephone office appears to be, like a locomotive, the safest refuge in a thunder-storm. Notwithstanding the number and range of location of telephone central stations, it has not been possible to obtain information of any injury by lightning to any person in such a place.

Telephone Lines.

Following the course of the lines from the subscriber's instrument, the aërial wires are of copper which has been treated by the hard-drawn process, as commercial copper is too ductile and has but little of the elastic property of resilience by returning to its original length when stretched by a load of snow or by a low temperature.

Hard-drawn copper might be classed as one of the modern inventions which the ancients stole, if the accounts of early implements may be accepted, but investigations showing that bronze had been supposed to be copper have absolved these people of anticipating the work of Mr. Thomas B. Doolittle, who produced hard-drawn copper by omitting the annealing during the latter part of the process, and obtained copper wire which retains the electrical conductivity of

commercial copper, while its tensile strength is doubled, and it is divested of the tendency to continually stretch under its own weight.

The substitution of hard-drawn copper wire for iron wire formerly in use has increased the limit of the telephone conversation under other equal conditions about four times, and by its better conductivity has diminished the waste of electricity used in telegraphy or electric lighting and transmission of power, or, what has been more important, has extended the limits of their application.

For local use, these wires are generally one-tenth of an inch in diameter, and for long-distance lines, larger wires about one-sixth of an inch in diameter are used.

The contact of these wires with those of other electrical circuits used for lighting or for power, to which reference has been made, is not the only difficulty, for the mere proximity of other wires conducting these powerful currents will, if they are of changing polarity, produce sympathetic currents by induction in the telephone wires, and, acting on the telephone, are the occasion of various noises which at times interfere with the transmission of speech through the telephone, furnishing examples of wireless telephony which are impediments to the usual service.

This interference by induction is minimized by transposing the telephone wires to various positions on the cross-arms, so that the result will be neutralized by imposing such conditions of position that these disturbing elements will counteract each other.

The wires of underground cables are laid in twisted pairs so that they are immune to inductive influences.

An aërial line is subject to the attack of all manner of disintegrating conditions—poles decay and break, branches fall from trees and wreck the wires.

It is as unfeasible to make a pole line equal to stress of weather beyond peradventure as it is to make the rigging of a vessel equal to the impact of all storms, for when a sleet storm builds the wires to icy lines, three inches in diameter, sail is set for the gale to sway the lines until the poles are broken.

During a recent winter, the destruction of aërial telephone, telegraph, and electric light lines in the New England States was estimated to be greater than the loss of shipwreck on the New England coast.

This breaking of lines has been prevented on local wires whenever it has been feasible to substitute aërial cables, each containing a num-

ber of wires, in place of the open wiring; but for long distance and toll wires it has been necessary for electrical reasons to retain open wires.

The gales on the summit of the Rocky Mountain passes are so severe that neither poles nor lines will withstand the stress of winter weather, although lines have been built with poles set only fifteen feet apart, yet the sleet builds them up to large dimensions which yield upon the impact of winter gales.

Communication, however, is permanently carried on along these routes by means of submarine armored cables which have been buried in trenches excavated among the rocks.

In addition to the facilities for concentrating forces for immediate repair in case of wreck, the lines are inspected by a patrol to give forewarning of imminent breakage.

These men brave the wilderness and face the elements through sun and through storm, from the miasm of southern swamps to the rocky fastnesses of western ranges, in the rigors of heat and in cold, all in order to give every assurance of human power that the response will be made when the telephone is taken from the hook. As in the other services of civilization, it can be truly said of the telephone service: "When we taste the spices of Arabia, we do not feel the scorching sun which brought them forth."

Difficulties with aërial wires are by no means confined to those occurring under the severe conditions of northern winters, for each country appears to have troubles of its own.

When telephone lines were first built in Mexico, it was naturally assumed that the absence of severe weather conditions would warrant the use of lighter wires and small porcelain insulators, but these lines proved of great interest to parrots and ring-tailed monkeys, who made nightly visits to the lines in such great numbers for gymnastic practice as to break the wires, and it became necessary to use as strong construction as in northern climates.

In forest districts wooden poles are occasionally gnawed down by bears, who hear the humming of the wires and vainly seek to break in to some hive of bees.

The King of the Belgians has had telephone wires placed over his territory in Central Africa—one line crossing a jungle 750 miles in length. Here it is not feasible to use wood poles, as is customary in other countries, as they are perforated by white ants, and it is necessary to attach the lines either to trees or upon tubular iron poles. These poles appear to be a great curiosity to elephants, whose inquisi-

tiveness emulates that of the blacksmith's apprentice who cut the bellows to find where the wind came from, and they pull up the poles with their trunks, probably in a search after the source of the humming noise, or perhaps to ascertain whether such strange-looking trees have succulent roots, and it is therefore necessary to secure the tops of these poles by guys running to higher trees wherever such conditions exist.

In Africa, as well as in India, the natives are prone to steal the wire, and it becomes necessary to remind them that "honesty is the best policy" by disconnecting the telephones from the lines during certain portions of the day, while the lines, instead of being used for telephonic purposes, are made part of a grounded circuit from a high-tension alternating current dynamo, and this application of science prevents any native from touching the wire twice.

In all countries wasps make nests in the recesses on the underside of insulators, and the proverb relating to those who live in glass houses does not restrain them from showing umbrage in the most pointed manner whenever their tenancies are invaded by linemen.

At the southern portion of the United States, it was found that certain small insects deposited their eggs in the tubes containing fuses, and the formic acid secreted by the larvæ corroded the fuses and opened the circuits, and it became necessary to encase the fuses in the most secure manner.

Along the South Atlantic coast, fish-hawks make their nests on poles, and the linemen are obliged to carry sheath knives at their belts ready for defence against the fierce attacks of the parent birds.

Every possible precaution must be taken to avoid contact between high-tension and signaling lines, and prevent the occurrence of, rather than to rely upon protective devices to defend the plant against, physical injury, because the operation of a protector suspends the service over that line until the operative parts have been renewed.

At cross-overs it is preferable that the high-tension line should be above, as its wires are of larger diameter and generally fewer in number than the signaling wires.

The simplest method to prevent contacts in such positions is to make the upper span so short that the radial distance from the lower wire of the upper span to the nearest wire in the lower span is less than the width of the upper span; and then to dead end wires to prevent overhauling in case of breakage occurring on adjacent spans.

In many instances this method of line construction is unfeasible,

because the poles for such a short upper span would interfere with the requirements of travel in a highway, and other methods of preventing contact in case of breakage must be adopted, usually by grills made of guard wires connected by slats transversely across them, or by nettings.

When different lines are parallel to each other, the distance between them should be so great that the higher line could not touch the wires of the lower lines if it fell toward it.

In all cases where high-tension and signaling wires approach each other, every precaution should be taken to provide against possible contact by use of heavy material in construction and guys and braces to the poles as may be needed to assure their stability, in order to prevent occurrences which would interfere with the continuity of the service.

Underground Wires.

The aërial lines pass from the poles into underground conduits in the congested parts of the cities, flying from the mishaps of storms and crosses to other difficulties which are largely those of greater expenditure and electrical problems.

The underground system is older than the aërial system of electric conductors in applied electricity, for a portion of Morse's invention of the telegraph consisted in methods of burying the wires, but the first seven miles from Baltimore laid underground in lead pipes placed in a plow furrow proved inoperative.

When a foreman on the work, because he could not bury the wires along the stone viaduct at Relay Station, placed them on poles, with cattle horns from a neighboring slaughter-house as insulators, the expedient proved so successful that the remainder of the line to Washington was built in this manner, and the first portion reconstructed.

The underground conduits consist of groups of continuous ducts, generally three inches in diameter, and made either of vitrified tile, cement monoliths reinforced with iron, or creosoted timber, but circumstances often lead to peculiar modifications, as at St. Paul, Minn., where the streets are catacombed with tunnels which are readily made through the soft white sandstone which underlies that city, and the telephone cables are attached to the sides of these tunnels. Some of these tunnels emerge through the face of the bluff, where grated doors furnish light and ventilation.

Every few hundred feet these conduits lead to an underground chamber for the purpose of obtaining access to the cable to provide

for branches to the service of patrons, and also joining the ends of sections of the cables together.

These underground cables consist of from two to six hundred twisted pairs of wires insulated with paper and the whole covered with a lead sheath.

The electrical difficulties of telephoning through underground conductors were at first prohibitive in their nature, but improvements enabled this to be done later, and in the face of conditions which rendered one mile of underground the equivalent of fifty-two miles of overhead wire; but in the modern cable one mile of underground is the equivalent of twenty-eight miles of overhead copper wire one-sixth of an inch diameter, or twelve and a half miles of overhead copper wire one-tenth of an inch diameter.

These conditions are so severe that on long lines it is necessary to pass around intermediate cities to avoid underground wires, and in the suburbs of large cities are switching stations by which connections may be provided to enable patrons to send their messages by branch lines direct into the cities, or permitted to continue on the main line to places beyond.

Conditions of safety and good service require that a telephone underground system should not also include lines of electric lighting and power circuits, and serious mishaps have occurred in the few instances where the attempt has been made to place these diverse types of electric circuits adjacent to each other in the same underground system.

The rapid corrosion of the lead sheaths of underground cables, even in localities where lead pipes had lain uninjured for many years, was an unexpected occurrence of the most serious nature; and it remained for the late I. H. Farnham, of the New England Telephone and Telegraph Company, to discover,* in August, 1891, that this impairment was caused by the return currents of the grounded circuits of the trolley railroad systems, whose passage through the earth, from the cars where they left motors to the ground plates under the generators at the central power stations, produced chemical effects similar in principle to those of electro-plating, by which metal was removed from the underground telephone cables, gas and water-mains, and deposited beneath the rails.

At the instance of Mr. F. S. Pearson, Chief Engineer of the West

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*Trans. American Institute of Electrical Engineers, vol. xi, page 191.

End Street Railway, in November, 1892, the currents used in trolley railroad practice were reversed in polarity from the customary method prevailing at the time, so that the trolley wire would be positive to the earth, and the return currents would tend to build up material on all continuous metallic underground construction until near to the central electric power station, where the electricity leaves such conductors for the ground plates under the generators operating the trolley system, and would therefore produce more active impairment by the removal of metal at this point, were it not for large copper rods connecting these underground pipes and cables to the ground plates.

This course reduced the difficulty in the measure that it was capable of being carried out in practice, for electricity follows divided lines in proportion to their relative conductivity, and a certain amount will follow along the underground conductors until it reaches a direct path of electrical conductivity leading to the ground plates.

This treatment of the problem appears to have been more satisfactory with continuous underground conductors, such as electric cables, than it is with underground pipes having joints of different electro-chemical equivalencies.

The divergence of the return currents from the rails has been reduced by bonding the rails together with copper rods, or by casting iron around the ends of the rails, and also the use of heavier rails.

Office Distribution of Wires.

The terminals of the underground cable at the telephone central station emerge from their lead sheaths and are spread out upon a large iron rack known as a distributing frame, where the insulated wires are equipped with protectors for the same purpose as those at the subscriber's instrument, and the wires are changed from the order in which they are received from the cable to another classification, and thence to a similar rack called the intermediate frame, where the wires are grouped to the individual operators, which latter arrangement may be changed from time to time, as the number of telephones to which an operator can give attention varies according to the character of the service; that is, a business house conducting much of its affairs by telephone, uses many messages a day and requires more of an operator's time than a residence, with its infrequent use of the telephone.

The Switchboard.

The function of the switchboard is merely to place the ends of the wires from one telephone in electrical contact with those of any other telephone in the exchange, with suitable signals for calling the operator and the party addressed, and this system has been amplified until one human voice can reach to districts including considerably more than half of the population of the United States; and the interlacing has been so complete that its service reaches the smaller villages.

The first switchboards were based upon the telegraphic device of placing any two of half a dozen lines in contact, and the further development merged the principle of the annunciator used in hotels or in passenger elevators, in which a falling target or shutter, called, in like manner, the attention of the operator. With the needs of the patrons, the switchboard grew, new features were added, and old methods became discarded; every conquest of improvement meant an abandonment of former devices.

In these new switchboards the dropping shutter has been supplanted by the flash of a lamp to signal the operator; the turning of a crank to generate a current for moving a shutter is no longer necessary, and the subscriber removes the telephone from the hook and is ready to begin; galvanic batteries are not installed at the subscriber's equipment, but the whole of the electric energy is supplied by storage batteries at the telephone central station.

When the subscriber removes the telephone from the hook, which is merely an electric switch arranged to be operated in this manner without conscious effort on the part of the subscriber, a small electric bulb about the size of the end of a lead-pencil and embedded in the switchboard becomes illumined with an opalescent glow which attracts the attention of the operator, who inserts a plug at the end of flexible conductors into a small socket perforating the face of the switchboard just above the electric light, and this corresponds to the telephone of the subscriber, and the socket guides the plug to contact with the ends of the wires from the subscriber's telephone, and the insertion of the plug in the socket also extinguishes the signal light.

A touch upon an electrical key places the operator's telephone in circuit with the telephone of the subscriber who hears the inquiry for the number wanted.

On receiving directions, the operator inserts the plug at the other end of the same flexible conductor into the socket corresponding with

the telephone wires of the party desired, and this lights one of a pair of signal lamps embedded in the table projecting from the front of the switchboard.

If, however, the operator hears a click, on inserting the second plug, this serves as a signal that the desired line is in use elsewhere on the board and the line is reported as being "busy."

It is more personal trouble for an operator to report a line as being busy than it is for her to complete the connection.

When the party called to the telephone removes the instrument from the hook to receive the message, this light on the table becomes extinguished.

After both persons have finished talking, the hanging of their telephones on the hooks flashes the pair of lamps on the table, which glow until the operator, perceiving the signal, pulls both of the plugs from their sockets.

If, instead of a subscriber at the same switchboard, one is desired at another exchange, the proceeding becomes more complicated, and many of the arrangements of the modern telephone central stations and methods of administration are designed to provide for this extension of the service.

When a call for a telephone connected to some other switchboard is received, as the operator cannot reach a line directly to the desired telephone, the call is transmitted by an office line to a special operator at another switchboard, where it is noted on a memorandum blank, and the time automatically recorded by means of a clock registering stamp; then the call is transmitted by trunk lines to the desired telephone central station, or it may be to some station which can reach the desired subscriber, and in some instances it is necessary to transmit the message through a greater number of telephone offices, each one building up the line by additions, and every operator also keeping, by means of the time stamp on memorandum blanks, a record of the hour and minute of each step from the initial call to the final termination of the conversation and the release of the lines.

As soon as an operator has finished the entries on a memorandum blank it is placed in a small orifice, where it is carried by air pressure, through tubes in a manner similar to the well-known cash carriers, to another department, where it is compared with similar memoranda made on the same conversation at other points on the line by clerks, and these form the authority for the charge for the toll service.

These memorandum blanks are compared by clerks, and must

balance as in other book-keeping, and form the authority for the charge for the service.

In some instances, where there is a great load of service on long-distance lines, the communication form one central station to another by the operators for the purpose of obtaining the desired party at the telephone is carried on by telegraphing over the telephone lines; for there are methods by which this can be done without interfering with the transmission of conversation at the same time on the identical wires, and these lines branch near to their terminals, where each class of electrical currents is transmitted to its proper instrument, whether of the telegraph or the telephone system.

A telephone switchboard is an exception to general forms of construction in that the cost per unit increases at a greater rate than the enlargement, and this is due to the fact that, as the operator who receives a call from a subscriber must be able to reach the terminals leading from the switchboard to any other telephone or to the switchboards at other stations, each set of telephone wires must have as many sockets and branches as there are operators' sections at the switchboard.

For example, in a small switchboard with two operators' sections, there would be two sets of such branches and sockets for each telephone line, while in a large switchboard with fifty operators' sections, there would be fifty sets of such connections for each telephone line instead of the two sets mentioned in the first instance, the number of this class of connections multiplying twenty-five times for each telephone, in order to enable each operator to reach all subscribers connected to that switchboard.

This difference in cost may be appreciated by reference to the material entering into the composition of a switchboard for 10,000 telephones and one for 600 telephones, the individual items in each being alike and of the same cost.

In the larger switchboard there are 2,500,000 soldered connections, or 250 to each telephone; and in the smaller switchboard there are 43,000 soldered connections, or about seventy-two to each telephone.

In the larger switchboard there are 10,000 miles of wire, or one mile to each telephone; while in the smaller switchboard there are 220 miles of wire, or about one-third of a mile to each telephone.

Many other details follow similar proportions, and in some minor items the ratio of cost per telephone is in favor of the larger switch-

board, but the whole expense per telephone is vastly greater for the larger switchboard.

There are other precedents in construction, where an increase in size adds disproportionately to the cost, as bridges, where the expense of a larger span is disproportionately greater than a smaller one of equal strength; and in like manner large pipe-organs cost more per unit of capacity than smaller pipe-organs.

Another instance of increased cost per unit of measure which is familiar to all is that of fabrics, whether it be an Oriental rug, wherein the cost of a large one is greater per square foot than a small one, down to ordinary sheeting, where cloth of full width for such purposes costs more than cloth of the same weight whose width requires one or more seams.

This increase of complication of detail growing upon itself would reach a prohibitive cost in large cities had it not been found feasible to depart from the original plan of one central telephone station in each city, and to introduce a modification by apportioning large cities into telephone districts, each with its telephone station connected to the others by numerous trunk wires.

A telephone switchboard is a marvel of complexity of detail in extreme contrast to the simplicity of operation, and no one person can have the repute of its design, but it is one of the few inventions which were made by the concerted effort of many experts working together for a purpose.

The mechanical intricacy of the modern switchboard may be well appreciated by the fact that, even with present methods of special machinery, and the organized application of skilled artisanship, it requires as long to make and install a large switchboard as it does to build and equip a merchantman, the time being from one to over two years, and the cost of the central station plant may reach $1,200 per foot of length for the larger switchboards, and perhaps half that cost per foot for a switchboard adequate for a city of fifty thousand inhabitants.

These central station costs are a small detail of the whole cost of the system, although it is the greatest concentration of value and forms the vital part of the whole exchange.

There is an exaggerated opinion of the damageability of a switchboard by water, and while it is perfectly true that it must be thoroughly dry for practical operation, yet switchboards have been thoroughly wet and restored to good service by drying out. It is the general

custom to provide water-proof covers for switchboards as well as for generators and motors whenever it is considered that there is any hazard of a water damage from fires in other parts of the building which might cause an interruption in the service.

One of the floating statements, which probably originated among the wheels in the head of some man set to the task of filling a funny column, runs to the effect that a glass of water would cause $1,000 damage in a switchboard, and the statement is absolutely a false one.

When a switchboard is started in the service, the elements of its active demolition begin; repairs and adjustments are necessary, extensions become needed for increased capacity, wear and tear has been outclassed by the more iconoclastic depreciation from subsequent invention, and in a few years the old board becomes obsolete, and the expensive apparatus is burned for the intrinsic value of the copper which it contains.

The requirements of perfect adjustment and continuous operation in a telephone system necessitate expenditures involving amounts beyond the dreams of avarice.

The charge for maintenance is far greater than that of the operation of the telephone system, being the greatest single expense. One-third of the gross revenue of a telephone company is necessary to preserve the plant in good order without any reference to the cost of extensions or of operation.

The Variable Use of Telephones.

The grouping of the use of the telephone may well serve as the basis of a sociological study of the habits and customs of a community. For studying the conditions of service for which provision must be made, the number of communications each hour of the whole day is taken from time to time, and the result plotted in a diagram whose hills and valleys indicate the relative load of service on the system.

Whatever disturbs travel also affects telephony, as may be noted by the increase in the number of calls, even to full capacity, during storms or in extremely hot weather.

In all cases, the night use between 7 P. M. and 7 A. M. is a small proportion of day use, and while these calls are largely of the important nature of emergency calls for fire department, physician, or police, yet in number they are slightly over one per cent. of the calls of the whole twenty-four hours; but the calls during the day begin to increase suddenly at some hour in the forenoon after the morning mail has

received attention, and approaches the congestion limit in the middle of the day, falling off suddenly as offices are being closed, and resuming activity in the larger cities late in the afternoon when arrangements for dinner or theatre are being made.

In the West the general business day is longer than at the East, while in New York the plotted diagram of telephone connections each hour indicates by the short duration of the intensely busy period that many might avail themselves of Charles Lamb's excuse to the Bureau officer in the East India Company's office, and make amends for being late at their desks in the morning by leaving earlier in the afternoon.

In New York the short time taken for lunch, or indeed its omission, does not make a sufficient break in business affairs to produce a depression in the curve, while in another city the depression is so great as to suggest a noonday dinner at home, perhaps followed by a nap of forty winks.

The Extent of Its Introduction.

The total amount of telephone line of the Bell system throughout the United States averages three and twenty-nine hundredths miles for each telephone instrument, and, excluding the long-distance lines, fifty-five per cent. of the wire is underground.

When a person calls up another telephone, the average line plant at his disposal is six and fifty-eight hundredths miles; truly, "it is cheaper to talk than to travel."

The long-distance wires interlace the whole system into a unity from the Atlantic to the Pacific, although a portion of the lines in the far west are not suited for long distance transmission; yet conversation from ocean to ocean is one of the expectancies of the near future.

This growth of the lines of the system is the result of a purpose to extend the use of the telephone to every town, no matter how small, throughout the United States; and in all of the cities and towns to put a telephone, at the most reasonable rates, "within easy and immediate reach of every person whose income is sufficient to permit him to ride on street-cars."

The extent to which this policy has been put into actual construction is indicated by the fact that, while the last census gives a record of 10,602 incorporated cities, towns, villages, and boroughs in the United States, there is telephone communication to 26,128 different settlements, and the continued growth of extensions postpones, year

by year, the saturation point of telephone service which has been recurrently anticipated by conservative persons.

The Operation.

The telephone business in its complications, on one hand, and its close relations with the needs of its patrons on the other, is one requiring active zeal.

As a certain French prisoner in the Bastille could always see an eye at a hole in an upper corner of his cell following his every movement, so with as vigilant though more agreeable espionage, there is always an ear waiting at the office end of a telephone line to take the directions of the subscribers in giving service.

Under American conditions, the equipment of the plant and its attendance must be adequate to give practically instantaneous service at all times, even though the demands at night are but slight in comparison to the requirements of the day.

Reference is frequently made to the low cost of telephone service in European countries, but it should be remembered that it is furnished under lower wages and material conditions far different from those of this country.

The Government owns the buildings, and the department does not pay taxes, rent, or maintenance; the Army Engineer Corps builds the subway as a Government charge; and the pole lines are built by another department without any charge to the telephone system for material or right of eminent domain.

The demands of American patronage require that the plant and attendance should be adequate to provide prompt responsive service; but in those countries there are so few toll lines that requests for long-distance service are received in the order of their application, and the patron must wait—be it minutes or hours—until a line is at liberty.

The methods of Oriental potentates who send their seneschals to agitate the pools in the palace yard in order to keep the frogs from croaking during the Shah's siesta, are repeated in two European monarchies whenever the emperor uses the telephone, as all the operators are obliged to leave their positions at the switchboard, and withdraw in military evolution from the room while His Majesty holds converse.

The striking feature of the two great applications of electricity which are used by the public, namely, the street-car and the telephone system, is that, however complex their mechanism, their use is extremely simple.

There is, however, no premium on ignorance in the use of the telephone by either subscriber or operator.

It has been a matter of slow growth for the subscribers at large to use the telephone in the best and simplest manner, and that is to speak clearly rather than loud, and to avoid the use of merely formal words in calling for the number wanted.

Nothing reveals more prominently the innate courtesy of a person than the manner of address over the telephone, whether to operator or subscriber.

Operators are prepared by a short course in a special training-school which differs from other institutions of learning, except West Point and Annapolis, in that they are under pay during the period of tuition.

The result of such systematic work in connection with improved apparatus in New York, which is cited as an example, because the exact statistics are at hand, has reduced the time of making complete local connections during the last five years three and nine-tenths seconds, which may appear a short time to any one, except when waiting at telephone,—or looking into a gun,—but this small amount of time when applied to all the telephone connections of the Bell system in the United States, amounts to 15,070 hours a day saved to the subscriber's time, or about five and five-sixths years in eight-hour days. The saving of time in disconnections, largely owing to the common battery switchboard signaling the operator by lights rather than shutters, enables the lines to be released, when a conversation is at an end, three and two-third times as rapidly as formerly, and this is of great advantage to the subscriber in making repeated calls.

These improvements in calling save 1,883 years of subscribers' time every year, and over three times as much time in disconnecting, a part of which time is available for the benefit of the subscriber, but no one has ever ventured to estimate the gross amount of time saved by the use of the telephone.

This vast system provides for about 14,000,000 calls per day, or nearly 2,000 calls a year originating at each telephone, and this means that an equal number of calls are received on the average telephone, so that each telephone averages being in use 4,000 times a year.

Why wonder, then, that these conversations, concentrated for the most part in the middle of the day, will sometimes interrupt another, and "the line is busy,—please call again"?

This interruption has been largely diminished of late years, first by

the installation of two telephone sets by a subscriber, one being omitted from the telephone book,* so that it is not subject to interruption by calls, and this instrument is therefore always free for use by the subscriber.

The second step in the development of the use of the telephone is an example of the modern principle of the conduct of business affairs in the subdivision of matters, so that each element may be attended to by one excelling in that branch; and in telephony this is done by concentrating the lines from the several telephones in an establishment to one desk, where, under the service of a skilful attendant, the desired connections are obtained.

Private branch exchanges are not limited to commercial houses and manufacturing establishments, but high office buildings are equipped with telephones as well as elevators during construction.

This concentration reduces the number of lines from the telephone central station to this group of telephones, and, while the commercial advantages of the method are so apparent that the number of these private attendants in New York is more than twice the number of telephone central station operators, yet it must be obvious as an underwriting principle that there is an advantage from an insurance standpoint in this arrangement, for as everything has some relation to the fire hazard, that of the telephone is based on the exposure of the wires leading to the subscribers' instruments to foreign currents, and if the number of these wires can be reduced from a pair leading to each telephone, down to two or three circuits leading to a normally open switching arrangement, which in turn can connect to any of these telephones, then the chance of occurrences resulting from foreign current is in like manner minimized, without reference to the defense afforded by the protectors.

Furthermore, the entering wires are equipped by protectors as may be required, near to the entering point; and the whole group being under the care of an experienced attendant, better service can be obtained, as in case of any interruption to one circuit, some other circuit can be used to call for necessary repairs.

This interruption to service has been reduced to a very slight matter, and this is generally owing to an enlargement of the plant, where the changes are made at night. In New York the interruption to each substation from all causes is one hour and twenty-one minutes a year,†

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* The Telephone Door. Angus S. Hibbard, Electrical Engineering, December, 1894, page 259.

† Trans. Am. Inst. Electrical Engineers, vol. xx, page 181, John J. Carty.

generally without the subscriber's knowledge, as is shown by the fact that the complaints are only one to 15,138 lines per day, or once in forty-one years per telephone.*

The subscriber to a telephone loses personal identity, and his name merges into a number.

When telephone central stations were first established, the names and positions on the switchboard of the subscribers were known to operators with strong memories; an epidemic of measles occurred in Lowell, Mass., and Dr. Moses Greeley Parker, a member of the Board of Directors, viewed with alarm, from his standpoint as a physician, the possible condition of affairs if more than two of the four operators should be taken with the measles, and proposed that the subscribers should be numbered.

His associates demurred, as they were of the opinion that the subscribers would give up their telephones sooner than submit to the indignity of being known by number, but in view of the contingency of the service being paralyzed they finally yielded, and to the surprise of all, the new arrangement was cheerfully accepted by the subscribers, who appreciated the improvement in service which resulted from the change.

Essential as the telephone is now to the conduct of affairs, no one can state, except as a general principle, why a person subscribes for a telephone.

While a large town uses more than a small one, the ratio of telephones to population differs materially in various places to an extent beyond what may be attributed to the personal energy of those in charge of local affairs; and in like manner the relation of the number of telephones to the number of horses, electric lights, business houses, assessed valuations, or any other of the details of census enumeration fail to give any basis of close comparison.

However, there are several lines of general similarity which cannot be tabulated in the logic of numbers.

Where highways are bad, there is a large amount of toll line telephone traffic. A hilly town uses far more telephones than a similar one on flat territory, and in some particulars one in a warm climate appears to give more patronage than a similar town in a cool climate; all of which shows that there is force in the injunction, "Don't travel; talk."

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* Trans. Am. Inst. Electrical Engineers, vol. xx, page 189, E. F. Sherwood.

In the use of the telephone there is originally one element of surprise to be mastered.

The senses are cooperative in their relations with each other, taste is rendered more vivid by smell, sound and sight accompany each other; with the use of the telephone there has been need of practice to accustom one to the sound of a voice through the telephone without the help of other senses to determine its position, which may be near or far.

The Arab proverb, "Speak, that I may see thee," does not apply to the telephone.

The impersonal question and its rebounding answer is developing methods of concentrated mental effort which are adding to the potentiality of the individual.

The Orientals are great users of the telephone, as the telegraph is not adapted to the transmission of their written languages, on account of the great number of their characters, and messages are necessarily translated into some modern language, and after receipt interpreted back into their languages, with the inevitable tendency to error. The Japanese are especially large users of the telephone.

The telephone can be used by Chinamen who understand each other's dialect, of which there are about seventy-five varieties in China.

There is a Chinese switchboard in San Francisco, at which the operators must know the four principal dialects of the provinces which furnish the immigrants to this country.

As an example, the sign for Telephone Office can be read by any Chinaman, but the pronunciation would be different, as noted by examples from two of the leading dialects, and its universality in this respect is comparable to Arabic numerals, which can be understood by all civilized nations, although read in far different words.

The telegraph has made correspondence more concise and checked the tendency to "degenerate into fine writing"; the type-writer is bringing the spoken and written English together, for the Chinese have not the monopoly of dual languages, and the telephone is making direct and definite propositions and replies in the three minutes between "hello" and "good-by."

Like Queen Victoria's published diary, it has given sanction to colloquialisms, and even slang, and imparted to words new significance not stated by the dictionary.

TELEPHONE OFFICE.

AS WRITTEN BY A CHINAMAN.

New Chwang Dialect.	*Mandarin Dialect.*		*English Translation.*
KO	CHIANG	講	SPEAK
DEN	TIEN	電	LIGHTNING
OU	YIN	音	SOUNDS
KO	KUNG	公	PUBLIC
SHEE	SZU	司	COMPANY

It appears that these changes originate with the subscribers rather than the telephone companies; for instance, a telephone central station is generally referred to as an exchange, while a telephone exchange, according to its use in patents, contracts, and by courts, is the telephone plant within a circle thirty miles in diameter, for the original concessions of the telephone company were like the Spanish land grants in the western hemisphere, except that the circles do not overlap, nor are their centers moved at the will of the stronger holders.

Long-distance Telephony.

The toll line service began with the line built from Boston to Lowell in 1879, and this revealed both the functional possibilities of the telephone and the great many technical difficulties which have been over-

come, and in the space of twenty-six years the length of long-distance telephone lines has increased from 27 to 368,000 miles. But these lines are not to be considered as comprising all of the lines outside of any municipality, as they can be attached to lines about 6,000,000 miles in length and, radiating at these points reach to the desired subscriber.

The long-distance commercial service may be considered to date from the New York and Chicago line, which was opened on October 18, 1892, by Dr. Alexander Graham Bell, in the presence of a concourse of persons eminent in electrical affairs; and on February 7, 1893, Gov. William E. Russell and a body of prominent Boston men opened the line from Boston to Chicago.

When a person uses a long-distance telephone, a large amount of property is at his exclusive service,—for instance, in speaking from Boston to Omaha, as one business firm does every morning, the value of the fraction of line and apparatus at their sole disposal is, at the present price of copper, $283,000, while it requires the service of over nine operators at the switchboards at various points along the line.

The weight of this copper is one million, one hundred and thirty-one thousand pounds, or five hundred and sixty-five and one-half tons, and the wonder is not so much in the fact that a human voice can cause vibrations in its unison throughout this immense mass of metal, even to its uttermost limits of 1,600 miles, with those delicate touches of tone which determine the individuality of one voice from another, as it is that the telephone is so delicate that it can catch these vibrations and transmute them into speech. Truly did Archimedes exclaim, "When I stamp, the world trembles!"

The Real Estate.

The permanent nature of the underground conduits of cities requires that telephone offices should be as permanently placed in relation to these conduits, and it has been necessary for the telephone company to buy land and erect fireproof buildings where the wires are placed underground, as it would not be prudent to be subject to the mutations resulting from leased buildings.

The telephone company is now among the largest real estate owners in the country, and it probably has the largest number of buildings of any single commercial organization, and a still larger number of holdings of real estate, and also the ownership of the largest number of fireproof buildings.

In order to make every feasible provision for the permanency of the

telephone service, the buildings erected by the telephone companies are, with the exception of a few having mill floors, entirely of fireproof construction, and the designs are especially made with a view to obtaining stability under heavy loads. and to afford resistance to fire.

They are equipped with subsidiary fire apparatus, and the windows opening toward exposures are provided with fire shutters.

In smaller towns, where special telephone buildings are not warranted, and it is necessary to lease space for central stations, the utmost care is exercised to select the best buildings available for the purpose, and these are generally that type of building well known in small towns, where the first story is occupied by a national bank on one side of the front entrance, and a savings bank or the post-office on the other side.

There is a general inspection of central station property, which includes reports on general order as well as matters pertaining to the service and the conditions of the electrical apparatus.

In addition to night watchman's patrol on such properties, notwithstanding the constant occupation of the operating room, there is a constant supervision of the central station apparatus against all disarrangements, which is equal in the larger central stations to an inspection of the plant every twenty minutes.

Wires are placed underground in cities, some of the apparatus is in duplicate, and reserved portions are stored at convenient points, and the operation of the whole plant is under a constant supervision. The electrical apparatus is frequently tested, inspectors patrol along the route of aërial lines, trials of service are made at subscribers' instruments, and the apparatus examined in addition to electrical tests made from the central station without the subscriber's knowledge; even the electrical condition of the earth as modified by return currents of the electric railroads is frequently measured.

All of these initial conditions and precautions of operation for the purpose of maintaining the permanency of the service have also reduced the fire losses on these properties to a nominal amount, that of the New York Telephone Company since its incorporation being less than five and one-fourth per cent. of the premiums.

In other manner than refraining from having cause to make claims, the telephone company has proved a most efficient ally of the underwriters' interests, for each instrument is a fire alarm, and in many towns the only fire alarm, and is always ready to transmit emergency calls to the fire department, the police, or other help in addition to the ordinary commercial and personal uses of the instrument.

Miscellaneous Applications.

The telephone habit is causing subscribers to use their telephones a greater number of times each day, and circumstances are finding new uses, which in turn become grafted into the system.

A few years ago, when an ocean liner was stranded for a few days on the New Jersey coast, a man rowed out to the vessel, with a telephone set attached to a twisted pair of waterproof insulated wires, which served as a submarine cable, which connected to a telephone line on shore, and officers and passengers used the line until the boat was pulled into deep water, and finished her voyage.

It is the custom to anchor vessels in the lee of the coral reef which forms one side of the harbor of Honolulu in the Sandwich Islands. When a vessel comes to her moorings, the local telephone company attaches a branch cable at one of the many taps of a telephone cable which runs along this reef, and passes it over the stern of the vessel, and also a telephone which is installed in the cabin, and in this manner provides facilities for transacting much of the ship's business by telephone, even to reporting to the custom-house authorities.

From this was but a step to the present custom of connecting steamers by telephone while they are lying at dock, and this may have been anticipated by the practice of connecting fire-boats by telephone when they are moored.

Express trains at the West are frequently connected by telephone at stations where there is a stop for a few minutes; and the trolley cars of long lines in Ohio have telephone booths.

The special train which carried the Commercial Club of a western city on an extended trip was equipped with telephones at each seat which furnished the passengers, through a private branch exchange, communication with each other and with a mixologist of rare skill who held sway at the life-saving station in the buffet car, and at stations attachments were made to the telephone lines of the general system.

The cars of the funicular railroad on Mt. Tom near Holyoke, Mass., are equipped with telephones, connected by sliding contacts to a pair of wires at the side of the track, so that the motormen on the two cars can communicate with each other.

Railroads, particularly trolley lines, are largely managed by telephone, and the installations at large terminal stations are on an extensive scale.

Wrecking trains are equipped with telephones which can be connected with a telephone line along the right of way, and communication established with headquarters of the company.

Business meetings and conferences are held by means of telephones, which are joined together in such a manner that the whole number, instead of merely any two, can hear what any one says.

The Board of Directors of a Chicago corporation has members also at Milwaukee, St. Paul, and Detroit, and meetings are frequently held with these men at their telephones taking part in the proceedings.

At Presidential conventions a person near the stage telephones in a low tone an account of the proceedings, which is repeated by another in a neighboring telephone station, where the wires are connected to a number of telephones, and these messages are repeated in like manner at each change until its amplitude extends over the country wherever there are telephone lines, and at various points the information is taken down by stenographers.

Political slates are shattered in the most iconoclastic manner by means of canvassing done over the telephone.

In hotels the telephone is used for calls from rooms to the office, obtaining quicker and more accurate service than can be secured by waiting for a bell-boy, by whom the message may be forgotten or distorted, and these room telephones can also be used throughout the general telephone system.

Oaths are administered over the telephone; it is against the rules of the company to utter them. Threats are made from the safe vantage of a sound-proof booth, and lawyers have been at variance as to alleged libels in the same manner. That lovers woo and swains propose over the telephone is an everyday remark, but a young man in Muncie, Indiana, had some difference with a miss, and was shown the door, with the injunction never to call again. Asking permission over the telephone a few days later to call again, her reply was to fire three revolver shots into the transmitter, so that the young man had good cause to remember that absence of body was preferable to presence of mind.

In the manufacture of steel the melted iron runs from the tuyeres of the blast furnaces into crucibles on cars, which take it to the steel converters a half mile or more distant. When the metal is flowing into the crucible, a boy takes a ladleful, which cools quickly, and is analyzed at once by a chemist, and the result telephoned to the steel superintendent, who is thus informed before the arrival of the

molten iron as to the amount of spiegeleisen to add to obtain steel of the desired characteristics.

Telephone lines penetrate mines, extend through air locks of tunnels and caisson foundations; they ramify about extensive manufacturing establishments and form part of the equipment of vessels; they accompany the advance of armies, and the commander is kept in communication with the firing line.

It is of great value in giving the results of target practice, especially with artillery.

None of the applications of the telephone furnish greater alleviation to humanity than its use in hospitals, particularly those devoted to contagious diseases. There have been several instances of pupils living at houses under quarantine, who continued their studies at home, recited their lessons, and successfully passed examinations over the telephone.

In short, its applications are becoming more extended as the emergency of yesterday becomes the precedent of today.

Telephone Rates.

As in the case of railway traffic, the cost of furnishing customers with the facilities for their communications is a problem whose details require close analysis, and the accumulated experience on this subject is applied to the benefit of customers throughout the long range, from the large establishment whose conduct of affairs requires an incessant use of telephones during the busy hours, and thence down through numerous subdivisions of service, with corresponding diminutions of rates, to farmers' lines, where twenty instruments on a circuit give a service which fills the need, and is well worth the moderate cost.

The fundamental unit of the cost of telephone service is based upon the use of the instrument of the number of the calls rather than the instrument itself as a basis, and the results of improvements in apparatus and methods of administration are continually diminishing the cost of telephone rentals.

The public has shared the results of these improvements by a steady reduction in rates, and it may be asserted that the telephone is the only public service which has voluntarily reduced its rates.

The extension of the telephone service, both in numbers and in purpose, is making it more of a necessity whose value is recognized.

This increase during the year 1905 amounted to 1,217,694 tele-

phones and transmitters and 1,372,480 miles of line wire, which, with its attendant construction, cost $50,780,906, being an increment of 27 per cent., which brought the whole number to 5,698,258 telephones, requiring 6,043,518 miles of line wire to reach their patrons.

This work is requiring extensive investment of capital to make these extensions and to build the plant in such a permanent manner as to give assurance of the continuity of this valuable service, and it is of the most favorable significance that this aspect of the system is being so thoroughly accepted by the patrons, who appreciate that its affairs must be conducted on a basis which will assure good and permanent service, and that it is essential that the service must be paid for at a price which will continue its quality and maintain the plant, giving a reasonable profit which will not only conserve present enterprises, but also attract additional capital as it may be needed for future growth of the business.

In recent times there have been many instances where the early history of public electric lighting enterprises has been repeated by telephone companies that gave service at rates which ignored the constant drain for maintenance and depreciation.

Some who have entered the telephone business in the spirit of commendable enterprise have learned too late that the elements of depreciation and the provision for future growth are of such moment that the estimated rates were too low, and that self-preservation required an increase, even though it was necessary to invoke legal aid to remove the restrictions on rates which were embodied in franchise and charter in perfect good faith that such provisions were to be kept to the letter.

It has been claimed that there have been errors in not ruthlessly charging depreciation and renewals into expense, but to charge them into construction and capitalize the amount with the inevitable sequence of logical results.

The experiences in other lines of industry during the last few months have furnished notable instances where every dollar wrongfully charged to investment, when it should have been charged to operating, directly impairs the capital and creates a deficiency which must be reimbursed by additional capital or take the same consequences as follow losses from any other cause which impairs capital.

As the telephone ranks as the most widespread application of electricity in its direct relation to the individual, so the business conduct of its affairs must be administered upon the basis of revenue sufficient

to maintain the plant and to earn a legitimate income on the investment.

Like all electrical enterprises, the forthcoming continuance of the increase in the number of telephones will require a corresponding augmentation in the amount of capital, which must, as in the case of railways, be obtained from investment outside of the revenues, as the results show that the standard upon which telephone rates are based does not provide for a sufficient surplus to furnish amounts adequate for such enormous increase in plant; but the problems of extension differ from those of the railway in that telephones are not installed until subscribed for, and therefore their earning capacity begins at once; and, in addition to this immediate service, any use which such telephones may make of the toll system increases the earnings of existing plant.

There is every reason to believe that the income resulting from the permanency of the patronage, and the present knowledge of the expenditures required for operation and maintenance, will combine to render such investments desirable and on a far more secure basis than in years agone, when an uncertain present and a conjectural future made the proposition far more indefinite than the present sound basis of telephone investments.

The electrical transmission of speech and its instantaneous reply is the last step in the progress of modern enlightenment in that concentration of effort and result which reaches to every phase of life in its modification of commercial and personal relations between individuals isolated from each other's presence.

DISCUSSION.

Mr. Woodbury (In answer to questions).—The telephone rate is fundamentally made up of the following divisions:

First: The maintenance of the plant in an effective condition, which without reference to enlargements, requires about 30 per cent. of the income from telephone rates. Second: Cost of operation; this simply includes the labor cost for the continuous operation of the system day and night without cessation. Third: The income on investment, which is absolutely essential for the service offered to the patrons of the companies, not merely to the extent that it may be an assurance of the proper condition and operation of property, but that adequate resources may be provided for the further extension of the plant to meet the demands for additional telephones. As long as a telephone company is patronized and its affairs administered in such a manner that it commends itself to investors as a solid, conservative, and profitable enterprise, so long will capital continue to purchase the stock or bonds necessary to build extensions

to the telephone plant. In this respect the telephone problem corresponds to that of the railways as to extensions of plant. It differs from the railway problem in that extensions of line and instruments at once begin earning, and also, through the toll connections, add to the earning power of the original plant. If telephone rates had been sufficient to pay for additions, the price of telephone service would have been at seriously restrictive and generally prohibitive rates.

Anything which I might offer on the subject of the automatic exchange would be from an outside standpoint. It is an ingenious device, which Mr. Lockwood credited with the advantage that it would not leave to get married. Its application in its automatic functions is limited to one switchboard. I cannot at this time enter into any consideration of the mechanical complexities or the cost of maintenance, or the relative speed of operation. I believe that the general opinion of the Bell telephone people with whom I am associated is that the public service operation of the telephone system requires the interposition of human intelligence, especially for the great amount of connection to other switchboards required in every town large enough to have more than one switchboard in its system, and the same opinion applies in even greater degree to the toll telephone service between different towns, which frequently passes through several switchboards; but there is doubtless a field for automatic switchboards in small villages near to larger towns, where local service could be cheaply furnished, and through one automatic signal the toll operator at a manual switchboard in adjoining town be reached for toll service.

The "ghost" or "phantom" system of making up a third circuit from the four wires comprising the two pair of telephone wires is widely used, especially by operators in arranging toll or long-distance connections.

The use of telephone lines for simultaneous telegraphy is done by the insertion of condensers in the line near the telephones and outside of the telegraph instruments. The direct currents used in telegraphy cannot pass through the condensers, which act virtually as insulators to the further conductivity of the telegraph current; but the alternating currents used in ringing and those used in telephony readily pass through the condensers. This permits the telephone wires to serve for telegraphy and telephony at the same time without either one interfering with the other.

There are no aërial cables in the long-distance service, but there is a repeating device which is applied to open wires, and I understand that its operation is successful, its chief functions being to extend the limits of long-distance telephoning and to permit the use of smaller wire on long-distance service. It is not yet in common use, being a very new device.

I do not know of any attempts being made to telephone across the Atlantic. The static capacity of the Atlantic cable is so large that it does not appear that any known method would be successful.

Successful experiments in telephoning over short distances without wires were made some years ago, but the art has not yet gotten beyond the experimental stage.

PAPER NO. 1019.

THE ECONOMIC PRODUCTION AND USES OF DISTILLED WATER.

HENRY LEFFMANN.

Read March 3, 1906.

MODERN chemistry has demonstrated that the term "pure" has, in reference to commercial products, only a nominal meaning. Absolute purity is with present available means unattainable. The nineteenth century was especially characterized by being a period of the development of precision in every science. The discovery of many delicate chemical tests led not only to recognition of the inapplicability of the term "pure" in most cases in which it had been used, but also to the recognition of sources of contamination not previously suspected, and, therefore, pointed the way for the removal or exclusion of such impurities.

Among materials conventionally termed "pure," and yet not entitled to the term, is water. In common language, we speak of "pure water," fully aware that the term is relative, and refers merely to real or supposed freedom from specifically injurious substances. The water termed "pure" for boiler, or other technical use, may often be termed "impure" for drinking.

From a very early period, mankind has recognized the liability of water to produce sickness. Long before anything was known as to the composition of water or of the ingredients ordinarily dissolved in it, or of the chemistry of its action in the system, the conditions that rendered it unsafe for use were in part, at least, known to civilized communities, and means were adopted to guard against these dangers. I had the honor to present to the Club, some years ago, a summary of the interesting features of the water-supply of ancient Rome, and I have elsewhere given some account of the supply in ancient Jerusalem. Many other ancient communities might be named in the same relation. In these cities, however, the industrial uses of water were of secondary moment. In Rome, for instance, public baths, street and garden sprinkling, and fountains were probably the chief applications of water in addition to the regular household uses. In technic uses, probably the dyer was the most liberal consumer. Nothing existed that can compare to the steam-boiler consumption or to that excessive water-waster of modern life, the system of water-carried sewage.

The problem of proper water-supply is seriously complicated by the urban tendencies of modern life. In this country, particularly, people are crowding into the cities at an accelerating ratio, and the density of population at many points is such that the normal water-supply is insufficient and so polluted that even that which can be obtained cannot be used. Penn, we are told, wanted his city to be merely a "green country town," the houses at intervals and set back from the streets. To secure a still more open arrangement, he set apart areas for parks; areas which seem now few and small, but which were, according to his light, ample. His successors, however, cannot criticize him, for with stupidity and fatuity as incomprehensible as disheartening, the development of the city has been allowed to go on without attention to the preservation of such open spaces. As that great enemy to proper municipal development, the operative builder, goes on covering territory with lines of small houses on narrow streets, the possibility of deriving water from the subsoil is abolished and it is necessary to draw still further upon the area outside of the city.

Natural sources of water may be conveniently arranged in four classes: rain, surface, subsoil, and deep. Of these, the first is nominally the purest, and is often free from all but traces of foreign matters, but it is liable to irregularity of composition and, in built-up sections, is nearly always so contaminated as to be unfit for drinking. In a non-populated or nearly non-populated area, subsoil water is usually of satisfactory character, the foreign matters being small in amount, but many exceptions occur, and subsoil water is often most unsatisfactory. Surface water, in its raw condition, is never entirely safe for drinking purposes. As regards mineral constituents it is often very satisfactory for manufacturing uses, but liability to turbidity is a serious objection. Deep water is often so rich in mineral matters that it is unsatisfactory for most uses.

These being the existing conditions, it is natural that the question of purification should have attracted attention at an early date and received increasing attention as years go on.

The recognized methods of water purification on the large scale have been so often presented for the consideration of this Club that I need do no more than enumerate them. Sedimentation, filtration with or without coagulants, and electrical sterilization have been widely tried, and have their enthusiastic defenders and bitter opponents. A recently devised special method of sterilization, namely, with copper

sulfate, has been earnestly advocated by its discoverers and a few others, but there are such obvious objections to its use, except briefly and in particular emergencies, that it can scarcely be considered as within the scope of municipal engineering.

Of the practicable methods above noted, filtration alone meets the manifold requirements of modern cities, for which water must be abundant, clear, colorless, charged with but little mineral matter and only traces of organic matter, living or dead. Sedimentation is of limited use in improving water, and although much has been claimed for the electrical methods of purification, they do not clarify the water or remove mineral solids, and most of them are expensive.

Filtration with aid of coagulants is a rapid process and finds useful applications in some cases, but it adds to the mineral content of the water and it has not been in favor for large operations. The simple gravity system of sand-filtration is costly in installation, and, apparently, only safe when careful expert supervision is constantly maintained.

For sanitary purposes, and in a limited way for technic purposes, the boiling of water is of use. It can easily be rendered sterile by this means and some mineral matters removed, but turbidity is not diminished and the operation as usually conducted is somewhat expensive.

The distillation of water is the only method for rendering it pure. It is well understood that even the best commercial distilled water is pure only in the restricted sense that it contains very little dissolved matters. For some special lines of research a sufficiently high purity can only be attained by supplementing the distillation by chemical methods. Thus, with the so-called "conductivity water" used in electrochemical work, a very high degree of approximation to true purity is obtained, but such a product has no commercial interest on account of cost.

The process of distillation was known at an early date. Aristotle knew that sea-water could be rendered substantially identical with fresh water by this method. The chemists of the early centuries of the common era, such as those often classed as the Greek alchemists, have given in their works figures of distilling apparatus, some of which are still in use in our laboratories in not very much modified form. The operation as conducted in the original form of still is simple in principle but wasteful of fuel. The water is heated to boiling and the vapor condensed by passing through a cooling pipe. All the heat

used is lost. Moreover, in the first portion of vapor a disproportionate amount of volatile impurities is present, while if the distillation is continued to dryness or nearly so, the concentrated solution of mineral and organic matters suffers reactions by which more volatile matter is formed and the distillate is again contaminated. For these reasons, standard distilled water includes only what is technically termed the "middle run of the still," some of the first portion being rejected and the distillation stopped before all the water passes over. By these modifications a further loss of fuel is caused.

The product of such a process, even when conducted with precautions, is not acceptable for drinking purposes. Its taste is either flat or suggestive of scorched organic matter. This has been often ascribed to the want of aëration, but in many cases, the sample is not materially improved by thorough aëration. Even if it is so improved, the additional operation adds expense, and, unless purified air is used, adds organic matters, living and dead. The disagreeable taste is often due to volatile matters, probably, as noted above, due to reactions between the mineral and organic matters. The taste, so far as I can judge from personal experience, is empyreumatic. It is regarded by most persons as very unpleasant, and limits much the use of distilled water for drinking, as well as the use of the ice made from it.

The economic production of a high-class distilled water is to be desired both from sanitary and technic points of view. Water being one of the articles which we consume in the raw state, its freedom from unwholesome constituents is most important. There is no necessity to call the attention of the members of this Club to the activity in that field of sanitary engineering which concerns the securing of a safe water-supply, nor is it necessary to more than allude to the great demand for water of good quality and constant composition for manufacturing purposes. One has only to look over the advertisements of the manufacturers of boiler compounds and water-purifying plants, as found in any technical journal, to appreciate the practical importance of this problem.

The economical manufacture of distilled water will find applications in many industrial plants, and will inure very greatly to the advantage of them. It will enable water to be obtained adapted in its chemical composition to the purpose for which it is to be used. It is a mistake to suppose that all industries require water of the highest attainable purity. Brewing, for example, is an industry that can use with advantage water that contains a notable amount of mineral substances.

In ordinary boiler-work, a small amount of scale-forming ingredients is often advantageous. Now, by mixing a good quality of distilled water with small proportions of raw water, any degree of concentration can be secured. Thus, if the available water contains forty grains of fixed solids to the gallon, a mixture of one gallon of this with nine gallons of distilled water will bring the total mineral content to four grains per gallon.

Another important application is the manufacture of artificial mineral waters and the beverages commonly called "soft drinks." As an example of the former class, lithia water may be mentioned. They have much vogue at present, but many that are sold have so little lithium that they do not deserve to be considered as medicinal waters, while others, rich in lithium salts, are also so rich in other mineral matters as to make their use unsatisfactory. An artificial lithia water can be prepared of satisfactory and constant composition, at a cost less than that of a natural water. The same will be true of iron and saline waters. They can be made to meet any therapeutic requirement.

For the manufacture of ordinary beverages, especially summer drinks, distilled water is well adapted, for one of the dangers from such beverages is the liability of impure water being used in their manufacture.

For laundry use, distilled water is exceptionally suitable. The saving of soap would be a considerable item in many places. One grain of calcium carbonate (commonly called carbonate of lime) will render useless six grains of dry soap, so that it can easily be seen that the use of a water containing four grains of calcium carbonate per gallon (not an unusual quantity) will entail considerable loss from the reaction with the soap.

Distilled water seems to be well adapted for drinking purposes. Statements to the contrary are occasionally made, but I cannot find that they are based on either physiologic principles or clinical experience. Of course, the disagreeable taste of ordinary distilled water prevents its use. No matter how wholesome it may be, persons will not drink it. To secure its general use, this taste must be removed, and a pleasant grateful quality given to it. To realize the commercial use of distilled water, the product must be cheap, of high approximation to absolute purity, colorless, odorless, and tasteless. It is my intention to describe an apparatus that I believe will accomplish these ends.

The essential principles of the apparatus are the employment of multiple effect, an economy of heat-exchange by using the hot distillate for heating the incoming water and the use of the last portions of vapor for heating the feed water to the boiler. Ingenious arrange-

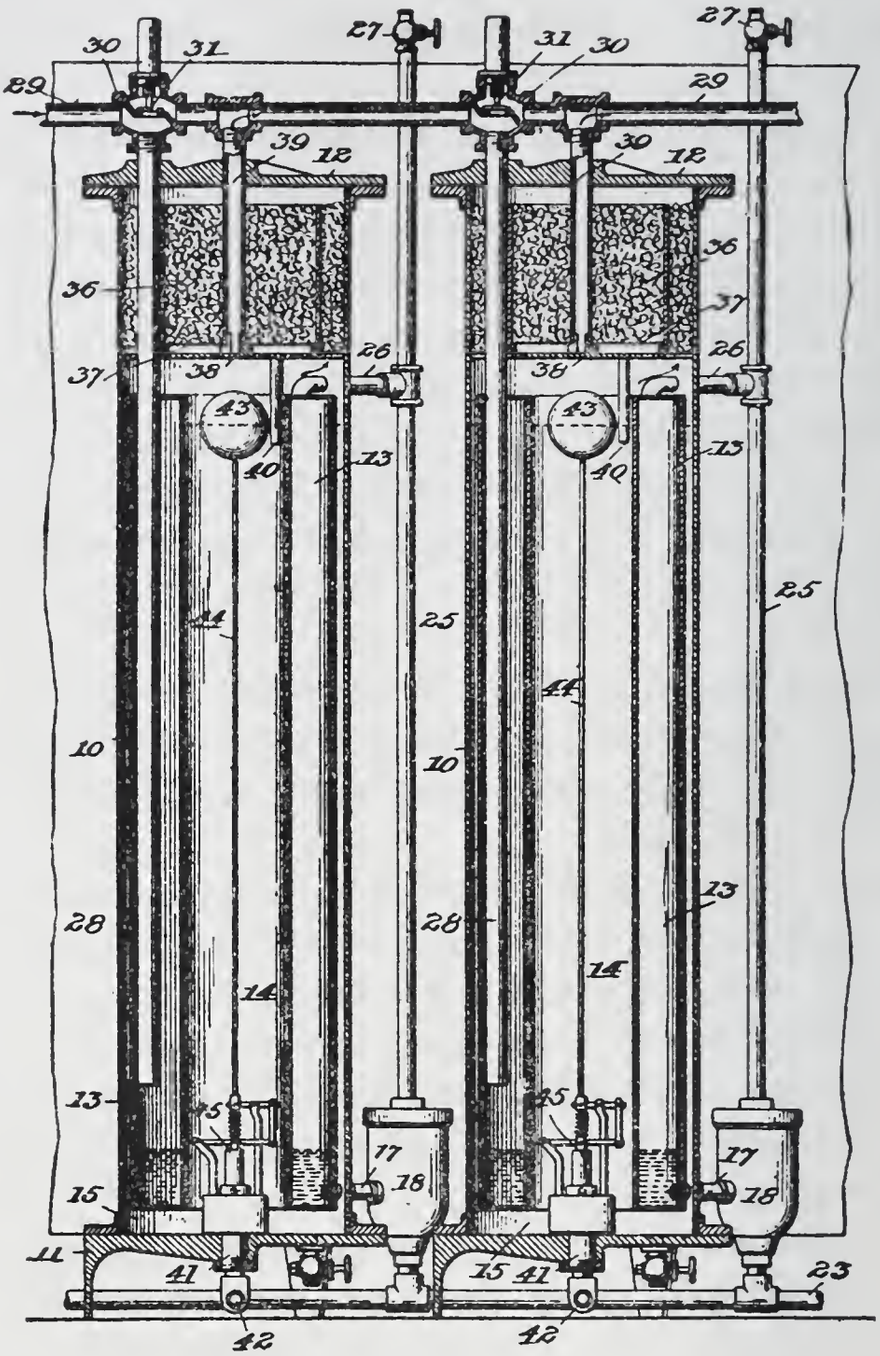

Fig. 1.

ments for maintaining sufficient steam-supply in each cell and for allowing the escape of objectionable volatile matters are also applied.

The apparatus is shown in different aspects in the annexed figures. Several subgenerators, conveniently termed cells, are arranged in a battery, which may be enclosed in an insulating cover. A section of a cell is shown in Fig. 1. It is a cylindrical casing, closed

at each end, except as to necessary openings for pipes and valves, and supported on a suitable base. In the cell is a condensing chamber (13), preferably in the form of a cylinder, through which passes a series of tubes that are open at both ends into the water chamber (15), with which also a central passage (14) communicates. Connecting with the lower portion of condensing chamber (13) is a duct (17) that leads to an anterior chamber (18), which is provided with a valve operated automatically by the rise and fall of the level of the distillate in the condensing chamber.

An equalizing-pipe (25) extends from the top of the casing (18) and is connected by means of a branch (26) with the top of the condensing chamber (13). This pipe (25) extends above the branch (26) and is provided in its upper end with a petcock (27), which allows of the escape of gases which accumulate in the condenser, as will be hereinafter more fully described.

Extending down into the condenser (13) to a point near the bottom thereof is a pipe (28) which extends up through the cell-cover and is connected with a main steam-pipe (29), which communicates with the primary generator and with each of the cells of the series in the same manner as now being described. This pipe is threaded into a pipe-fitting (30), which contains a check-valve (31) for regulating the admission of steam to the succeeding parts of the apparatus. This check-valve in this instance is provided with a stem which fits loosely into a hollow nipple which is threaded into the casting. A spring is interposed between the end of the stem and the top of the casting for exerting the necessary tension of the valve. By turning the nipple the same can be adjusted so as to increase or diminish the tension of the spring and thereby regulate the opening of the valve. The upper ends of the cells are provided with double-celled coke-receptacles (36), comprising an outer annular and an inner circular chamber. The outer annular chamber communicates directly with the steam-chamber below it, by which means steam may arise through it and its contained coke. The inner circular chamber is closed at the bottom and contains a horizontal screen (37), raised a little therefrom, upon which the coke rests, so that steam after passing upwardly through the outer annular chamber may pass downwardly to the small space below the raised screen. From the center of this bottom screen is a vertically arranged pipe (39), open at its bottom and in communication with the space in the bottom of the said central coke-chamber, and the upper end of the said pipe (39) extends

through the top plate (12) and is connected by means of a suitable coupling to the steam-main (29) to one side of the check-valve heretofore described. A drip-pipe (40) is secured in the bottom of the central coke-chamber and enters the central passage (14) of the condensing chamber below the water therein, so that any condensation which collects in the coke-chamber will be carried back into the water-chamber.

In the lower portion of each of the cells is a water-inlet (41), which communicates with the water-chamber of each cell and also with a pipe (42), which is common to all of the cells. An automatic valve (45) is provided for this water-inlet, which is adapted to be operated by a float (43), which is connected by means of stem (44) with said valve. This valve (45) is adapted to close the passage and shut off the incoming water when the said water has reached a height sufficient to raise the float (43). The bottom of each water-chamber is provided with a wash-out valve, in order that the said chambers may be properly cleansed of sediment.

In operation the steam is admitted from the primary generator through the medium of a pipe to the generator (13) of the first cell of the series to a point a short distance above the bottom of the said condenser. In the meantime water has been admitted into the cells from the bottom thereof, and the water-chamber surrounding the condensers is filled to the proper height, when its inflow will be cut off by float-valves. The heat from the condenser (13) coming in thermal contact with the water in the surrounding water-chamber gradually heats said water until it evaporates into steam of a pressure slightly less than that in the condenser (13). This flow of heat causes the steam in the condenser to condense into water, and the distillate thus formed accumulates in the bottom of said condenser and passes off through the medium of the pipe (17) and the automatic valve in casing (18) to the pipe (19), which is common to all of the condensers and through which it is conveyed to the cooling-cell and thence to the charcoal-cell, after which it is ready for use. The surface of the distilled water in the bottom of condenser (13) is close to the outlet end of the steam-inlet pipe, and this surface is thus always maintained very hot, so that it has a repellant action on the gases mingled with the steam, which are thus prevented from being absorbed by the distillate. As the outlet-pipe is below the surface-level of the distillate, the hottest surface layer is always maintained. The second body of steam which has been generated in the upper portion of the water-

chamber (10) passes through an opening and through the coke in the upper chamber, where any entrained water and certain gases therein are eliminated, and thence it passes through a screen and up a pipe to the main and pipe of the next cell to the condenser (13) of that cell, where the said steam is condensed and generates a third body of steam from the surrounding water. This last body of steam passes in a like manner to the next succeeding cell and the process gradually extends through each cell of the series until it reaches the last cell (9). This last-produced steam may have been so reduced in pressure and temperature as to be insufficient to evaporate its surrounding body of water, but will serve to heat said water to a high temperature, and this water is conveyed through the medium of a pipe (40) to the

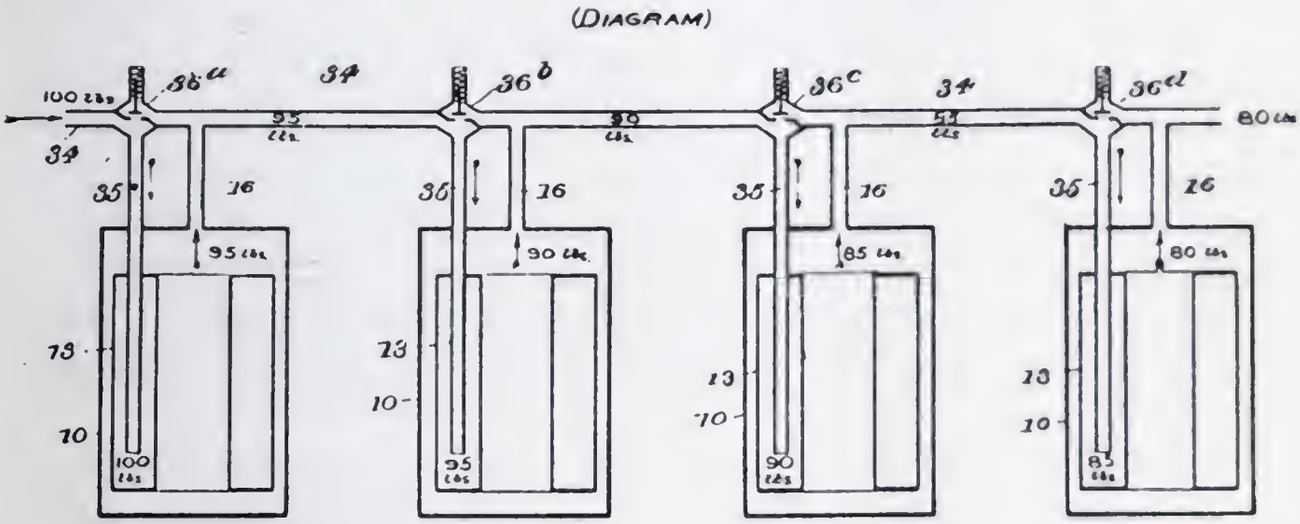

FIG. 2.

primary generator, so that the heat contained therein can be utilized in said primary generator.

An important feature consists in maintaining automatically a constant difference between the downwardly-stepped temperature and pressure between the condenser and evaporator of each cell. This is accomplished by correcting any accidental variation from this difference by the automatic introduction to each evaporator of a fresh reinforcing body of primary steam at the exact constant of difference in temperature and pressure which it is desired to maintain between the condenser and evaporator of each cell. This will be made clear by reference to the diagram (Fig. 2). In this figure, for simplicity, only the annular condenser (13) and inclosing evaporator (10) are shown coupled to the steam-supply pipe by pipes (35 and 16) and the several automatic pressure-valves (36^a, 36^b, 36^c, 36^d) of the

several cells. Now, if steam be taken at one hundred pounds and it is desired to have a difference of pressure and temperature of five pounds between the condenser (13) and evaporator (10), then all the valves (36^a, 36^b, 36^c, 36^d) are set to open at a difference of five pounds on opposite sides. Then in the first cell the pressure will be 100 pounds in condenser (13) and 95 pounds in the surrounding evaporator (10), and so on through the series. It is found, however, that practical conditions do not permit of realization of an indefinite extension of this effect, and if any one cell is unfavorably affected, the efficiency of the system is lost. The apparatus provides for automatic reinforcement of any such loss in any evaporator, by taking steam from the primary generator by means of the above valves (36^a, 36^b, 36^c, 36^d). To illustrate, suppose cell 2 should lose by radiation or leakage 10 pounds of its standard pressure. It is obvious that all the succeeding cells would partake of this loss, but the valve 36^b automatically opens and admits steam until the pressure is established at the standard difference on either side of the valve. This arrangement of valves permits also of drawing steam at any time from pipe 34, between cells, without affecting the standard difference of pressure.

Actual tests of this apparatus on a large scale have shown its efficiency. The following is a condensation of a report made by experts in boiler practice:

The duration of the test was twelve hours, from 3.35 P. M. to 3.35 A. M. The total yield of distilled water was 39,765 pounds (4768 gallons). On this basis the output would be 397⅓ gallons per hour.

The amount of steam used by the still, determined by weighing the feed water to the primary generator, was 6698 pounds. Dividing the total distillate by the steam used, gives 569 pounds of distillate per pound of steam. The coal consumed to generate the above steam was 828 pounds, hence the boiler produced 8.09 pounds of steam per pound of coal, and 1 pound of coal yielded 48 pounds of distillate. The average temperature of the feed water was 140° F. The coal consumption is not a fair record for the boiler, as it was run at only a small fraction of its normal rating. At least 10 per cent. higher efficiency could be obtained with the boiler at or near its normal rating, consequently a greater yield of distillate per pound of coal.

The actual test shows 12,899 gallons of distillate per long ton of coal. With standard boiler economy, one long ton of coal should give about 14,832 gallons of distillate. With coal at $3.00 per long ton, 1 cent in coal should produce 49⅓ gallons of distilled water.

The quality of distillate produced by this method is excellent. The fixed solids are often as low as 3 parts per million, equivalent to about $\frac{1}{6}$ grain per gallon. When kept for a few hours in ordinary glass bottles, water takes up appreciable amounts of mineral matter, hence, after storage, this distilled water may show ten or fifteen parts per million, but even this is below the fixed solids of most commercial distilled waters, and is entirely unimportant in technic or sanitary relations. As concerns organic purity, the water meets the most exacting requirements. The taste is agreeable.

The question of a double supply of water, one cheap for general purposes, and the other of higher class for personal uses, has often engaged the attention of engineers. It was discussed at a meeting of this Club about twelve years ago in connection with a paper by me on the water-supply of Philadelphia. Ancient Rome had a sort of double supply, and Paris has it at present. If distilled water of good quality can be produced at a price closely approximating that of filtered water, the practicability of such a double supply becomes a question which sanitary engineers cannot afford to disregard.

The comparison between filtration and distillation must be made as follows: Taking, for example, the proposed supply for Philadelphia, the cost will probably be from five to ten dollars per million gallons, with the end of supplying the few millions of gallons needed for personal uses. There is no need to use filtered water for washing and flushing, or for fire and most technic purposes. If the cost of the total supply is, therefore, assessed against that small portion for which highly efficient filtration is necessary, the cost per million gallons will be great. The logical plan is to use large subsiding basins for the general supply and a system of mains, and supply, in a separate system of smaller dimensions, pure water for personal uses and for such establishments as require it. It would be, of course, necessary to meter this high-class supply and to charge higher rates than would be charged for the lower-class water.

DISCUSSION.

P. A. Maignen.—I think the paper states that rain-water is not always pure. It occurs to me, however, that rain-water can be taken as a type of pure water. It is not absolutely pure, chemically speaking, because it contains gases from the air and, it may be, micro-organisms, spores, and suspended particles of various kinds taken from the atmosphere and from the roof upon which it falls.

We can, however, obtain pure rain-water if we wish, as has been done sometimes in China, by spreading clean sheets some little time after the beginning

of the rain and collecting the water falling on same in clean earthenware pots sunk in the ground. Such water keeps well and may be classed as pure water.

Deep water has been alluded to as being sometimes not good. That is so; it may be saturated with salts of lime and magnesia or with iron, but I am surprised that the author has not made mention of the fact that such waters are now being treated in England and in this country, with great success, by what are known as water-softening processes, whereby the objectionable earthy salts held in solution by the hard water are precipitated and removed from it by chemical reaction, precipitation, decantation, and filtration. Such waters are rendered perfectly suitable for industrial purposes, laundry, boiler, and even drinking purposes. The system is applied to the water-supply of several towns in England and in many mansions in the country where the water-supply is hard.

The paper states that sand filters are not safe. I think this has hardly been shown to be a fact. Sand filters, like distilling apparatus, can be ill-used or abused, and under certain conditions they are quite capable of producing water. This is not the time to extend one's self on this subject. I wish simply to submit that it would not be right to say that there is nothing safe except distillation for the purification of drinking-water.

I understand the paper to recommend the use of distilled water mixed with a portion of hard well-water for boilers. It would be a very expensive proposition to distil water for feeding boilers. The same may be said of the suggestion that distilled water should be used for laundry work. Laundries can soften their water and filter it at a cost not exceeding 5 cents per thousand gallons. The distilled water which the author recommends costs, according to his own showing, 1 cent for 50 gallons for coal alone, to which must be added the cost of labor, depreciation, interest on investment, etc. The coal alone at 1 cent per 50 gallons would cost $200 per million gallons. Considering that it is possible to produce absolutely pure water by means of filtration for $15 per million gallons, inclusive of capital charges and operation, it is hardly to be expected that distilled water will be a successful competitor with water that is filtered or softened.

With regard to the apparatus described, it may be all right mechanically, as far as the distilling part is concerned, but I venture to suggest that the filter is in the wrong place. It is a mistake to combine two such different factors as filters and distilling apparatus. Distilling is one thing, filtering is another. The two processes should be carried out in separate apparatus.

Coke is good as a filtering material, but it is not as good as charcoal. Bone charcoal is better than wood charcoal. If you confine these materials in closed vessels and filter the water hot, you do not get the full benefit from the porosity of these materials. At the normal temperature charcoal holds condensed in its pores fourteen times its volume of air. When heated, all gases are driven away and one of the most valuable properties of charcoal or other porous material is lost.

To obtain good distilled water the raw water should not contain any organic matter and it should be filtered before distillation so as to get rid of materials which produce bad gases, and it should be filtered also after distillation in order to remove the dissolved metals taken from the apparatus itself and aërate the water.

I should like to ask the author how it is that the fixed solids, which are said to be only three parts per million when the water comes out of the distilling

apparatus, become fifteen parts after remaining a few hours in the glass. Is the distilled water so pure that it dissolves the glass and saturates itself with silica? If not, what is it?

With regard to the question of double canalization which has been mentioned here this evening. You all know that it has been my hobby in all discussions on municipal water-supplies. It does seem stupid to wash streets with sterilized water. At the recent Tuberculosis Exhibition in Philadelphia, at which noted physicians have been telling the people how dangerous it was to spit on the pavement, a man in the audience suggested that the present system of cleaning the streets by brooms and sending the dust into our lungs was wrong. No satisfactory answer was given, but it is evident that it would be better to wash the streets than dust them. In Paris the streets are washed at night with water that is not filtered, but is plain water drawn direct from the river, like that used in Philadelphia for the fire service in the busy parts of the city. This water, when used by the people for industrial purposes, or watering gardens and the like in Paris, is sold at 12 cents per thousand gallons. Another set of pipes conveys to the houses spring or filtered water, which is sold at 24 cents per thousand gallons. When this water is used for power purposes the user is charged 48 cents per thousand gallons, so as to discourage the abuse of the good water.

The paper states that the cost of the filtered water in Philadelphia will be from \$5 to \$10 per million gallons. This is not very clear. If we consider that the improvement and filtration of the water-supply of Philadelphia will cost about \$30,000,000, the interest taken at 3½ per cent. and the depreciation at 1½ per cent. will amount to \$1,500,000 a year. If we add to this the cost of operating the filters, which may be estimated at \$5 per million gallons, on the assumption that the whole consumption is 300 million gallons daily the total cost of operation will be:

$$300 \text{ M. G.} \times 365 \text{ days} \times \$5 = \$547{,}500.$$

The fixed charges and cost operation will therefore amount to \$2,047,500. If the consumption is 300 million gallons daily, the total cost of each million gallons will be:

$$\frac{\$2{,}047{,}500}{300 \text{ M. G.} \times 365 \text{ days}} = \$18.70.$$

If the consumption is only 200 million gallons daily, the interest on the plant and depreciation will be the same and the cost of operation will not be materially different. However, on the same basis we should have with the lower consumption:

Interest and depreciation	\$1,500,000
Operation—	
200 M. G. × 365 days × \$5.00 per M. G.	365,000
	\$1,865,000

or—

$$\frac{\$1{,}865{,}000}{200 \text{ M. G.} \times 365 \text{ days}} = \$25.50 \text{ per M. G.}$$

When this sum is added to the present cost of raising and distributing the water in Philadelphia, it will be found that the present selling price of 4 cents per thousand gallons or $40 per million gallons will have to be raised considerably to make both ends meet.

I would ask the author what is meant by the word "alkali" as applied to the waters of the west and southwest of the United States. If it is brackish—that is, contaminated with common salt—no chemical process nor filtration system can make it potable. It should, therefore, be distilled, and there may be in those countries a great field for the invention described here this evening. But if the impurities in so-called alkaline waters consist principally of lime and magnesia, then they can be purified, as stated before, by water-softening process and filtration combined.

J. C. Trautwine, Jr.—The argument for the dual system of water-supply, to which Mr. Maignen has referred as "double canalization," seems to be based chiefly upon the fundamental error that the quantities of water furnished to dwellings are insignificant compared with those furnished to factories and used for the extinguishment of fires, flushing of streets, etc.

As long as this erroneous view is entertained, it is only natural that we should be asked: "Why go to the expense of filtering the enormous quantities of water used in manufacturing, etc., whereas all that need be filtered is the small quantity used for domestic purposes?" As a matter of fact, the domestic consumption usually forms by far the larger portion of the total consumption.

In the Water Bureau, while we had no means of ascertaining accurately, or even of estimating closely, the impression was that about 90 per cent. of the whole supply goes into the domestic consumption, and only 10 per cent. to manufacturers, etc. Of course, one able-bodied manufacturer uses and wastes more water than goes to many dwellings combined, but the number of dwellings is so much greater that their total consumption greatly exceeds that of the manufacturers. Even a very large fire, although of course it diminishes pressures in its immediate neighborhood, makes only a small demand upon the system as a whole; and the quantities of water required for the fires of a year are quite negligible in comparison with the total consumption.

There is another popular error which may have something to do with the favor with which the dual system is often regarded. The public seems (and naturally enough) to be under the impression that the pumping stations and reservoirs of our water-supply represent the larger portion of the cost of installation; whereas here, again, the very opposite is the fact. A few years ago the Water Bureau of Philadelphia undertook an estimate of the cost of the existing works, with the following result:

Pumping Stations	$4,173,638.00
Reservoirs and stand-pipes	5,615,643.00
Distribution	24,861,970.00
Total	$34,651,251.00

Any system, therefore, which calls for a double system of pipes, requires careful scrutiny on the side of first cost before it is adopted.

I quote the following from my report as Chief of the Bureau of Water, for the year 1895:

"Another difficulty is that of deciding upon the dividing-line between the two qualities of water supplied and the purpose for which they are respectively to be used. It would seem only natural that the quality of the poorer water would suffer by the distinction. The ultimate destiny of the dog branded with a bad name is proverbial, and it is altogether likely that the less desirable water would soon become unfit for such purposes as washing, either of the person or of clothing, as, indeed, the water which we are now obliged to drink too frequently is. It would also, no doubt, soon be found unfitted for many manufacturing purposes, such, for instance, as those of the brewer."

Samuel S. Sadtler.—Mineral constituents have a considerable influence upon the taste and healthfulness of drinking-water, and it may be that distilled water for continuous use might not entirely take the place of natural pure waters containing salts possibly essential to our systems.

Reference has been made to distilled water being unpalatable. For the reason stated, I do not believe it could taste like an average natural water, although if the distillate is allowed to run from the still hot it does not taste so flat, owing to the fact that the warm water does not dissolve some gases—probably arising from decomposed organic matter—to the same extent as cold water.

The President.—I would like to hear a discussion of the mechanical consideration of this apparatus. From the author's description it seems evident that it is essentially a multiple effect evaporator to which has been added charcoal chambers for further purification of the water. It does not, however, follow the rules generally observed in designing multiple effects apparatus, and it would seem that its capacity must be very much less than that warranted by the expense of construction. Multiple effect evaporators are generally designed to handle shallow bodies of liquid, so that all of the heating surface will effectually boil the liquid in contact with it, whereas, this apparatus has such a great depth of liquid that the bottom layers would not boil on account of the extra pressure due to this depth. Furthermore, provision is generally made for a violent circulation in order that full use may be made of the heat-transferring power of the heating surface, but no provision of this kind seems to be apparent in the apparatus under discussion. It is also customary to lead the condensation from one effect into the next in order to make use of and save the heat in the condensed liquid, which would appear to be impossible in this apparatus. Neglect of these features would not affect the economy of operation, but must seriously decrease the capacity of the plant, and we would like to hear the opinion of others on these features of the apparatus.

Edwin S. Hutchinson.—The question of pure drinking-water, though very much discussed, does not receive the amount of critical attention at all commensurate with its importance.

As is well known, the pathogenic potency of organic matter in water is destroyed by boiling, yet, regardless of the boiling, some of that soda, lime, magnesia, or iron (one or more) still remains in solution, and, being taken into the system, injures the kidneys, causes arterial sclerosis, and damages other organs and tissues.

A few years ago I received a very interesting and instructive object-lesson

on the subject under discussion, when a large works, located well up toward a dividing ridge where the mountain streams were small, needed an additional water-supply for boiler and domestic purposes. A six-inch well was driven down about five hundred feet, and when the vertical steam-pump, directly over the well, was started, it was assumed that an ample and satisfactory supply of water was secured. There was a strong taste of iron in the water, but as we have all been taught from early childhood that iron was an essential element in the human system, and as all knew that every year thousands drank of the waters of the chalybeate springs scattered all over the country, it was thought that the best possible domestic water-supply had been obtained, speaking both physiologically and hygienically. It was soon observed, however, that a large percentage of the men were not working regularly; while they were not sick enough to be confined to the house, yet they were lounging about, many complaining of loose bowels. Nearly all the members of the speaker's family, including himself, were similarly affected. As the well-casing was driven down into the solid rock and thoroughly cemented, there could be no organic impurities in the water, and yet local physicians could not explain the cause of the trouble. The situation was described to a University of Pennsylvania professor, who happened to be visiting in the region, and he suggested at once that the trouble might be due to the iron in the water, which disagrees with very many people. The situation was watched very carefully and it was soon discovered that the blondes were unaffected, while the semi-brunettes and brunettes were kept from duties a large percentage of the time. It is to be borne in mind that this working-out of the problem extended over several months, as, for a long time, it was fully believed that a thoroughly hygienic water-supply had been obtained. It was finally and satisfactorily demonstrated that the iron in the water was the real cause of all the trouble, and the conditions were met by putting down a series of shallow wells for domestic water-supply; and in a few months thereafter the population recovered its normal healthy condition. For my own family I had a small still on the kitchen range, and only distilled water was used for drinking and cooking purposes. Since that time, from observation, consultation, and reading, I have become fully convinced that in our solid food we generally get more than we require of iron, lime, and other salts, and that therefore our drinking-water should be as free from them as possible. Water is nature's universal solvent, and therefore is the great distributing agent in the human system, and we destroy its value as such distributing agent to just the same extent as that to which we load it down with mineral impurities.

It being assumed, then, that distilled water is the only water suitable for drinking and cooking purposes, the great economic problem for us engineers to solve is how can this water be provided conveniently, and at such cost as to bring it within the reach of all, both rich and poor. I consider it to be one of the great problems of the age.

The paper is very interesting and illuminating, and has brought the subject fully before us.

James Christie.—The softening of water for use in steam boilers is now extensively practised throughout the country, more especially in districts where the contents of mineral solution is large. The lime and soda treatment is used,—modifications of the original Clark process,—the various methods in vogue differ-

ing in the mechanical details employed to regulate and control the supply of the reagents. These methods are applied with comparative economy when large quantities of water require treatment; and when properly regulated, yield results sufficient for the purification of boiler supplies and similar purposes. But this system is not effective in separating all the mineral matter found in water. For example, common salt is not precipitated by this treatment. Salt is not uncommon in the deep well-waters of the Middle States, and it causes injurious corrosion in steam-boilers. The apparatus described in the paper should supply water of a high standard of purity, and is doubtless a useful instrument to employ where very pure water is an essential. It is not clear that it presents any economy as compared to the ordinary vacuum process with multiple effect. The five-stage vacuum process gives about the same economy of evaporation as in the system described, and while more machinery, such as pumps and condensers, may be necessary in the vacuum process, yet this system permits the use of low-pressure steam, with the choice of utilizing the high-pressure steam for power or other useful purpose before it passes to the evaporators.

For the production of artificial ice a high degree of cleanliness and purity in the water is desirable. The method usually employed, of condensing the exhaust steam of the engines, yields water not always satisfactory to the taste, and frequently tainted with the lubricants of the cylinders. The employment of multiple-effect evaporators suggests itself as the sure remedy, and I know of no reason why this apparatus is not employed in the ice-manufacturing plants, except the cost of installation.

Henry Leffmann.—I regret that the technical engineering features of the apparatus have not been more extensively discussed. Taking up some of the points noted, I have first to say that while rain-water is often considered pure, it is rarely, if ever, so in cities; even in the open country and after a long rain it often contains both suspended and dissolved matters. When collected from metal roofs it is very liable to contain dangerous impurities. In one case in which I was consulted, some years ago, it was thought possible to get water for a lighthouse located some distance from land, by collecting the rain-water from the roof of the residence building, but this had been covered with so-called "roofing tin," which is iron coated with an alloy containing much lead, and the latter metal had dissolved in appreciable amount. I doubt very much if the Chinese method described by one of the speakers would be acceptable in this locality.

I note what was said concerning the cost of filtered water per million gallons; it is more expensive than I thought. I did not mean to be understood as saying that filtration is inefficient. On the contrary, I regard it as most efficient and necessary whenever surface water is used for drinking. Experience has, however, amply shown that filtration systems require constant expert supervision to maintain their efficiency.

The increase of the dissolved solids in a sample of distilled water standing in glass is due to solution of some of the constitutents of the glass, probably, in most cases, the alkali. This action is well established. The current U. S. Pharmacopœia allows a maximum of 75 parts per million (a little over 4 grains per U. S. gallon) for distilled water. This is probably too large, but it indicates that the action is much more than nominal. In some delicate operations of analysis,

glass tubes cannot be used for collecting distilled water, on account of the matters dissolved.

The solids in the so-called "alkali waters" of the West are often sodium chlorid, sodium carbonate, and calcium carbonate. I think that the apparatus I have described will find valuable applications in dealing with such waters.

The wholesomeness of distilled water has been often challenged, but I know of no data either from physiology or practice that supports this view. The limited experience so far available seems to indicate that the solids necessary for the vital functions are fully supplied by the food. All over the world, water containing very small amounts of solids is being used. Some mountain-spring waters are as pure as commercial distilled water.

The question of double service is so largely one of constructive municipal engineering that I am not competent to go into it. I desire, however, to point out that Philadelphia now has a double system of considerable extent, and that, while it is true that the domestic use of water is the more important, it is also true that a large proportion of such domestic use in modern American cities is such that an inferior water would be entirely satisfactory. For flushing, bathing, laundering, and that great Philadelphia nuisance, pavement-washing, a water clarified by sedimentation with a little coagulant would be sufficient.

The statement by one of the speakers that the mineral solids in drinking-water are the cause of changes in the arteries, cannot be proved by clinical experience or physiologic knowledge at present; it is, therefore, merely a personal opinion. Similarly the account of the case in which the water-supply seemed to be connected with peculiarly selected manifestations of illness, is unfortunately incomplete. The analysis of the water is not given, nor the identity of the person who made the diagnosis that the iron in the water was the cause. In the lack of these and other important data, I cannot but do otherwise than express regret that the speaker has placed these statements so positively on record.

MEMORANDUM OF INFORMATION CONCERNING THE LATE THEODORE SPENCER.

THEODORE SPENCER was born on August 19, 1870, at Camp Douglas, Utah. He was the oldest son of the late William C. Spencer, Surgeon in the United States Army during the Civil War. He died suddenly at his late residence, 2017 Locust Street, on Sunday evening, January 28, 1906, of acute peritonitis.

He entered the Massachusetts Institute of Technology, from which institute he was graduated an electrical engineer in 1891. His first professional duties were with the Thompson-Houston Company, which was later the General Electric Company of Lynn, Massachusetts. After a short term with this company he entered the engineering department of the American Bell Telephone Company at Boston.

The records of the patent office bear evidence of his inventive ability and skill while engaged in experimental work in the laboratories of the Bell Telephone Company. He was largely responsible for the development of the common battery system, whereby the cells at the instruments of the telephone subscribers were done away with, and the storage battery at the central office substituted; and it was principally through his work that this system, which is now in general use throughout the world, was brought to perfection.

The first large common battery installation in the world was made in Philadelphia at No. 406 Market Street, and Mr. Spencer was sent here from Boston in October, 1894, as Superintendent of Electrical Equipment to supervise the work.

Later he was made Engineer of the Bell Telephone Company of Philadelphia. He rapidly earned advancement to the position of General Superintendent, and later General Manager; and at the time of his death he was General Manager, Vice-President, and one of the Directors of the Bell Telephone Company, and of the Delaware and Atlantic Telegraph and Telephone Companies; and was also Vice-President and Director of the Diamond State Telephone Company.

Mr. Spencer was elected an active member of The Engineers' Club in December, 1897, and shortly afterwards presented to the Club an exceptionally able paper on telephone engineering.

Although an engineer by training, and possessed of a broad tech-

nical knowledge, Mr. Spencer was endowed in a remarkable degree with executive ability, and with that most valuable of all qualities, "common sense." He was logical and far-sighted, and when his keen judgment had determined on the course to be followed, his executive abilities enabled him to obtain his results economically and quickly.

He was an able leader and inspired all his associates with his enthusiasm and thoroughness.

His uniform courtesy and thoughtfulness, combined with his logical and clean business methods, won for him the respect and admiration, not only of engineers, but of all with whom he came in contact. To his friends in the Club he was ever ready with advice and kindly assistance in any engineering matter in which his advice was sought.

Under his management the telephone business in Philadelphia and vicinity was enormously expanded and he kept steadfastly before him the duty of giving to the public an efficient and comprehensive telephone service.

In 1898 he married Miss Helena Carroll Frazier of Philadelphia, who, with a son and daughter, survives him.

In his short life he had won his way to the top through his unusual abilities, and had acquired a high reputation in the telephone field, not only in this country, but also in Europe. He had before him a future more brilliant even than his past, and his death was a great loss to the engineering profession.

Wm. C. L. Eglin,
Carl Hering,
Philip L. Spalding.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, January 6, 1906.—President Comfort in the chair. Eighty members and visitors present.

Mr. Percy H. Wilson read a paper on "The Raymond System of Concrete Piling," and one on "The Saving of Power House Sea Wall at Annapolis, Md."

Annual Meeting, January 20, 1906.—President Comfort in the chair. Ninety-four members and visitors present.

The Treasurer reported the names of seven active members who had been dropped from the rolls because of non-payment of dues.

The Secretary reported that the following members had been advanced to the active list: Holstein DeHaven Bright, Stanley G. Child, Kern Dodge, John A. Frick, W. Herbert Gibson, Chas. W. Lummis, W. A. McIntyre, John Reilly, Jr., J. A. Simons, Irving B. Thomas.

President Comfort then read the annual presidential address.

The Tellers reported the election of James A. Brown, E. B. Smith, and G. Edw. Smith to active membership, and Lewis R. Ferguson, John S. Haug, and John M. Weiss to junior membership.

The Tellers reported the election of the following officers for 1906: President, Thos. C. McBride; Vice-President, Washington Devereux; Secretary, Walter Loring Webb; Treasurer, Geo. T. Gwilliam; Directors, F. E. Dodge, Wm. Easby, Jr., and Francis Head.

Business Meeting, February 3, 1906.—President McBride in the chair. One hundred members and visitors present.

The Secretary announced the death of Mr. Theodore Spencer, active member of the Club. The President appointed the following Committee to prepare a memorial on the death of Mr. Spencer: Philip L. Spalding, Wm. C. L. Eglin, and Carl Hering.

Mr. C. J. H. Woodbury (visitor) read a paper on "The Telephone System of Today."

The Tellers reported the election of Harry P. Hiltner, Edw. C. Moore, Arthur H. Pratt, and Frank A. Wheeler to active membership; Chas. B. Gamble to junior membership, and J. B. Lober to associate membership.

Business Meeting, February 17, 1906.—President McBride in the chair. Eighty-seven members and visitors present.

Mr. Edwin A. Moore (visitor) read a paper on "By-Product Coke Ovens in America; Past, Present, and Future, during Two Decades."

The Tellers reported the election of Chas. A. Hexamer, J. Duncan Jaques, C. J. Reed, and Geo. L. Watson to active membership.

Upon request of Mr. Henry G. Morris, the Secretary read the following Preambles and Resolution:

"WHEREAS, In the engineering requirements of the City of Philadelphia, occasions have arisen in which it has been deemed necessary by the municipal authorities to call in for consultation and construction the services of consulting engineers in connection with the design and construction of public works required by the municipality, and

"WHEREAS, The practice heretofore has been to obtain the assistance of non-resident consulting engineers, to perform these services, and the necessity for ignoring the merits and attainments of resident engineers not being apparent, it is, therefore,

"*Resolved*, That The Engineers' Club of Philadelphia deprecates the action of the municipal authorities in ignoring the attainments of the engineers resident in this community and the inference from this action that engineering talent competent to deal with problems arising in the design and construction of public works cannot be found in this city and respectfully request that hereafter the qualifications of resident engineers be considered at least upon the same basis as those not resident here.

"Proposed by HENRY G. MORRIS
"Seconded by WM. COPELAND FURBER."

Under the rules no action could be taken, and it was moved and carried that the Preambles and Resolution be printed in the next notice and brought up for action at that time.

BUSINESS MEETING, March 3, 1906.—President McBride in the chair. Eighty-seven members and visitors present.

The Secretary read a memorial of Theodore Spencer, deceased.

The Secretary announced the death of Mr. Max Livingston, active member of the Club. The President announced that he would appoint a Committee to prepare a memorial regarding Mr. Livingston.

The Tellers reported the election of E. P. Coles, Justice C. Cornelius, F. Joseph Miller, O. G. Smith, and Chas. H. Thumlert to active membership, and Wilbur E. Fawcett to junior membership.

After some discussion on the Preambles and Resolution it was moved that they be laid on the table indefinitely, which was carried by a vote of 46 to 10.

Dr. Leffmann read a paper on "The Economical Production of Distilled Water and Its Applications."

BUSINESS MEETING, March 17, 1906.—President McBride in the chair. Seventy-six members and visitors present.

The President announced the appointment of Mr. Falkenau as a delegate to the Two Hundredth Anniversary of the Birth of Benjamin Franklin.

The Tellers reported the election of Martin Nixon Miller to active membership; T. Bertram Genay to junior membership, and J. E. Lord to associate membership.

Mr. Harrison W. Latta read a paper on "The New Sea Wall at Annapolis, Md."

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Special Meeting, January 6, 1906.—Present: President Comfort, Vice-President McBride, Directors Dallett, Davis, Devereux, Easby, Loomis, and Quimby, and the Secretary and Treasurer.

The report of the Finance Committee was adopted.

The report of the Executive Committee for the fiscal year 1905 was accepted as read.

It was decided that the meeting of the Board for January 20th should be held at 4 P. M.

The President announced as a Committee to prepare a memorial on the death of honorary member General Herman Haupt, Messrs. John C. Trautwine, Jr. B. S. Lyman, and Wm. Easby, Jr.

Regular Meeting, January 20, 1906.—Present: President Comfort, Vice-Presidents McBride and King, Directors Dallett, Devereux, Easby, Loomis, and Quimby, and the Secretary and Treasurer.

The report of the Treasurer for the month of December was read and accepted as follows:

Balance November 30, 1905	$1935.79
December Receipts	1646.86
	$3582.65
December Disbursements	847.19
Balance December 31, 1905	$2735.46

The Information Committee reported the engagement of four gentlemen to present papers before the Club.

The invitation of the American Philosophical Society to appoint delegates to the Bi-Centennial Celebration was referred to the incoming President.

The resignation of Mr. F. E. Dodge as Alternate Teller, dated January 6, 1906, was duly accepted.

The letter of Prof. Edgar Marburg as Secretary-Treasurer of the American Society for Testing Materials, expressing the thanks of their Executive Committee for privileges in the use of the Club House, was read and ordered filed.

The following resignations were accepted: Franklin Baker, Jr., Chas. H. Cramp, F. V. Hetzel, E. G. Marble, C. E. Schermerhorn, F. H. Shelton, H. T. Townsend, and J. W. Wright.

The Secretary was authorized to buy a letter case, card case, etc.

It was ordered that the rental of the safe deposit box from the Girard Trust Co. be discontinued.

Organization Meeting, January 27, 1906.—Present: President McBride Vice-President Devereux; Directors Dallett, Easby, Loomis, and Quimby, and the Secretary and Treasurer.

The President announced the following Committees: *Finance*, W. P. Dallett, Wm. Easby, Jr., Joseph B. King; *Membership*, Wm. Easby, Jr., F. E. Dodge, W. P. Dallett; *Publication*, Henry H. Quimby, Wm. Easby, Jr., Francis Head; *Library*, Washington Devereux, Joseph B. King, John T. Loomis; *Information*, Francis Head, Henry H. Quimby, Washington Devereux; *House*, John T. Loomis, Washington Devereux, F. E. Dodge; *Auditors*, H. W. Spangler, Richard L. Humphrey, W. B. Riegner; *Tellers*, W. E. Bradley, I. W. Hubbard, H. P. Cochrane; *Alternate Tellers*, Emile G. Perrot, Alan Corson, W. W. Nichols.

The Advertising Committee was re-appointed.

Regular Meeting, February 17, 1906.—Present: President McBride, Vice-Presidents King and Devereux; Directors Dallett, Easby, Dodge, Head, Loomis, and Quimby, and the Secretary and Treasurer.

The report of the Treasurer for the month of January was read and accepted as follows:

Balance December 31, 1905	$2735.46
January Receipts	2408.10
	$5143.56
January Disbursements	264.51
Balance January 31, 1906	$4879.05

It was moved and carried that a deposit of one thousand dollars be made in the Colonial Trust Co. and five hundred dollars in the West End Trust Co.

It was moved and carried that the salaries of the Treasurer and Secretary be the same as last year, and that of the Janitor was advanced from $47.50 to $50.00.

Regular Meeting, March 17, 1906.—Present: President McBride, Vice-Presidents King and Devereux; Directors Dallett, Dodge, Head, and Quimby, and the Secretary and Treasurer.

The report of the Treasurer for the month of February was read and accepted as follows:

Balance January 31, 1906	$4879.05
February Receipts	877.83
	$5756.88
February Disbursements	515.86
Balance February 28, 1906	$5241.02

The President announced that he had appointed Mr. Falkenau as a delegate to the Two Hundredth Anniversary of the Birth of Benjamin Franklin.

It was moved and carried that the Library Committee be granted an additional appropriation of $100 for special purposes.

The Secretary was authorized to purchase the Elliott Addressing Machine at a cost of about $75.

ADDITIONS TO THE GENERAL LIBRARY.

FROM A. GIBB MAITLAND.

Mineral Production of Western Australia.

Geology and Auriferous Deposits of Southern Cross, W. A.

Geology and Auriferous Deposits of Mount Morgan, and Notes on Geology and Ore Deposits of Mulgabbie, W. A.

Further Report of the Geological Features and Mineral Resources of Pilbara Goldfield.

FROM EDW. ORTON, STATE GEOLOGIST.

Geological Survey of Ohio, 4th Series, Bulletin No. 7.

FROM BOSTON TRANSIT COMMISSION.

11th Annual Report, June 30, 1905.

FROM THEO. N. ELY.

Locomotive Tests and Exhibits at Louisiana Purchase Exposition.

FROM EDWARD GODFREY.

Godfrey's Tables.

FROM LYMAN P. CLARK.

Principles and Practice of Artificial Ice-Making and Refrigerating.

FROM JOSEPH T. RICHARDS.

Record of Transportation Lines of P. R. R. for year ending Dec. 31, 1905.

FROM THE INTERSTATE COMMERCE COMMISSION.

Railways in the U. S. in 1902. Parts 2, 4, and 5.

FROM WAR DEPARTMENT.

Report of Chief Engineer for 1905.

FROM CHIEF ENG. OF THE BOARD OF PUBLIC SERVICE.

Report on Sewage Purification at Columbus, O.

FROM A. ELLIOTT KIMBERLY.

Practical Advantages of the Gooch Crucible in the Determination of the Total and Volatile Suspended Matter in Sewage.

Relative Applicability of Current Methods for the Determination of Putrescibility in Sewage Effluents.

A Comparative Review of Current Methods for the Determination of Organic Matter in Sewage.

THE ENGINEERS' CLUB OF PHILADELPHIA

1122 Girard Street

OFFICERS FOR 1906

President

THOS. C. McBRIDE

Vice-Presidents

Term Expires January, 1907

JOSEPH B. KING

Term Expires January, 1908

WASHINGTON DEVEREUX

Directors

Term Expires January, 1907

W. P. DALLETT

HENRY H. QUIMBY

JOHN T. LOOMIS

Term Expires January, 1908

F. E. DODGE

WM. EASBY, Jr.

FRANCIS HEAD

Secretary

WALTER LORING WEBB

Treasurer

GEORGE T. GWILLIAM

Clerk

MARJORY LAMBE

STANDING COMMITTEES OF BOARD OF DIRECTORS

Finance—W. P. Dallett, Wm. Easby, Jr., Joseph B. King.
Membership—Wm. Easby, Jr., F. E. Dodge, W. P. Dallett.
Publication—Henry H. Quimby, Wm. Easby, Jr., Francis Head.
Information—Francis Head, Henry H. Quimby, Washington Devereux.
Library—Washington Devereux, Joseph B. King, John T. Loomis.
House—John T. Loomis, Washington Devereux, F. E. Dodge.
Advertising—Geo. T. Gwilliam, Walter Loring Webb, Henry H. Quimby.

MEETINGS

Annual Meeting—3d Saturday of January, at 8 P.M.

Stated Meetings—1st and 3d Saturdays of each month, at 8 P.M., except between the fourteenth days of June and September.

Business Meetings—When required by the Constitution or By-Laws, when ordered by the President or the Board of Directors, or on the written request of five Active Members of the Club.

The Board of Directors meets on the 3d Saturday of each month, except July and August.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XXIII. JULY, 1906. No. 3

PAPER NO. 1020.

BY-PRODUCT COKE OVENS IN AMERICA: PAST, PRESENT, AND FUTURE.

EDWIN A. MOORE.

Read February 17, 1906.

THIS subject doubtless introduces to many of those present practically a new and what is considered by many an infant industry which has sprung up with others in this country during the past ten or twelve years. Its importance is becoming more generally recognized, and its position is more substantially established, year by year, as the long-existing merit of the industry, as practised abroad, unfolds its benefits to our American engineers, manufacturers, and financiers.

Like all other innovations of great moment which have revolutionized various important industries in this country, and doubtless all other countries, there have been many barriers, seemingly insurmountable, which militated against the introduction of this one. The by-product, or more properly the retort, coke oven was akin to various industries which were given birth in European countries almost contemporaneously with the early practical demonstrations of the steam-engine, locomotive and steam-boat. Therefore, confining ourselves to the realm of engineering accomplishments, it is only necessary to refer to the experiences in the early efforts of Watt with the steam-engine; Stephenson with the locomotive; Fulton with the steam-boat; Howe with the sewing-machine; Pullman with the sleeping-car; McCormick with the harvesting-machine; Bell with the telephone;

Edison with the electric light; Westinghouse with the air-brake; Siemens with the furnace, and our neighbor, John Fritz, in the development of the steel business, together with hundreds—yes, thousands—more or less deserving of note because of their achievements during the past and present generation, to enable you to comprehend the early struggles necessarily encountered by those first engaged in the development of by-product coke ovens or retorts for the distillation of coal for the recovery of gas and its by-products. It is noteworthy that William Murdock, who introduced the gas retort, was an associate of James Watt in their early joint efforts in mechanical pursuits.

Notwithstanding the early recognition of the value and merits of the by-product coking process, little is recorded of the continuous efforts made to establish the industry upon a practical commercial basis from the latter part of the eighteenth century until about the middle of the nineteenth century, when it is recorded that in 1856 one Knab, a Frenchman, built some retort coke ovens adapted to the saving of tar and ammonia, and utilizing the gas for illuminating purposes. Improvements upon the Knab ovens were made by Simon and Carves and C. Seibel, of France; Albert Hüessner, of Germany, and Coppee, in the development of non-recovery ovens.

It remained, however, for Dr. C. Otto & Company, of Thalhausen on the Ruhr, Germany, to stem the tide of prejudice growing out of the more or less serious impediments to an unqualified success in the production of metallurgical coke, brought about by the failure of those previously engaged in the industry, to promptly recognize the demands for the slight changes and improvements needed to establish, upon an assured basis, an acceptable system. To this end Dr. C. Otto & Company introduced the very valuable addition of the Siemens regenerator, with its important economic advantages,—which improvement was patented by Gustav Hoffman,—combining therein the Otto-Hoffman system of by-product ovens.

It is to this type of oven that your attention is particularly invited this evening, since it has been the writer's privilege to be identified with the design and construction of a number of the plants installed in this country during the past few years.

Notwithstanding the fact that the early struggles of the pioneers in the development of by-product ovens, from 1856 to 1881, had been crowned with great success by the valuable practical improvements culminating in the Otto-Hoffman ovens, which were rapidly being installed throughout Germany and elsewhere on the continent, the in-

dustry was not introduced into this country until 1894, when Dr. F. Schniewind, now vice-president of the United Coke and Gas Company, who was identified with the industry abroad, was commissioned by Dr. C. Otto & Company, the parent company, to introduce the system into this country. After repeated efforts through various channels of exploitation, the interest of capitalists was enlisted, resulting in the formation of the Otto Coke and Chemical Company, which was soon enlarged into the United Coke and Gas Company, organized by the late William L. Elkins, Jr., of this city, who was its first president, and remained so until his untimely death in March, 1902. The creation of this industry, due to the far-sighted recognition of its future possibilities by Mr. Elkins, should, therefore, make the subject of special interest to this Philadelphia engineering body.

In spite of the rapid growth and unqualified success of by-product ovens abroad and the known fact that the antiquated beehive oven was rapidly becoming obsolete, it became a very difficult task to interest blast furnace people in the consideration of the matter. It is the old, old story over again, with which doubtless many of you are familiar, though in different lines, of the struggles, trials, and hardships, intermingled with hope, spurred on by the faith that finally triumphed, in securing the interest of the alert officials of the Cambria Steel Company, Johnstown, Pa. They sent experts abroad to investigate the merits of the system, actuated primarily by a desire for some method of coking the vast quantities of coal which practically underlaid their steel plant, but which on account of its low volatile nature could not be coked with commerical success in a beehive oven. The report of the investigators, upon their return, recommended the installation of a trial plant as the most feasible if not the only possible means open to them, for the profitable utilization of this underlying coal. It requires but slight reflection to recognize the enormous advantages accruing to them in cheapening the production of their steel plant with such a natural condition of mining the coal, coking it, and utilizing it in the conversion of metal, almost within the shadow of the blast furnace stack.

A careful investigation and test of the coal by Dr. Schniewind revealed its extraordinary character, bearing out the full knowledge of its peculiar swelling nature, dreaded by the Cambria people as a potent element sure to work havoc with the oven construction to such an extent, possibly, as to make the plan impractical, even though the type of oven, with its regenerative system, might be successful with such a

low yield of gas from such a low volatile coal to coke the same. Furthermore, necessity for washing the coal imposed an additional hardship by requiring more gas to heat the ovens to drive out the moisture from the washing process.

Less courageous persons than those handling the affairs in connection with this proposition would doubtless have dealt a severe blow to the introduction of the industry. It was a bold stroke, considering the apparent impossible nature of the undertaking; failure meant a very severe defeat. On the other hand, success meant the establishment of an excellent foundation upon which to build later achievements. Courage prevailed. A contract was entered into for a plant consisting of 60 ovens, arranged in two batteries of 30 ovens each, with a complete by-product plant for the treatment of the gas and recovery of the tar and ammonia. Success crowned the efforts of the undertaking, excellent coke being produced from the seemingly uncokeable coal. Thus was launched, against most trying odds, this new industry in this country.

Contemporaneously with the installation of this plant for the Cambria Steel Company, the Solvay Process Company, of Syracuse, N. Y., installed a small plant consisting, as we understand it, of about 12 ovens for use in connection with their soda-ash plant. We believe this plant was later enlarged to 30 ovens, thus forming the nucleus of a business enterprise involving the organization of a by-product coke oven company known as the Semet-Solvay Company. The ovens installed by them are heated by means of longitudinal horizontal flues without regenerative system, while the Otto-Hoffman ovens, which we are especially considering, employ vertical heating flues arranged in combination with the regenerative system previously alluded to.

The constructive features of a general plant are shown in Fig. 1. It must be borne in mind that the ovens proper are designed to be sealed so as to be as nearly air tight as possible, inasmuch as the carbonizing or distillation of the coal takes place by the radiation of the heat from the vertical flues penetrating the side walls. The method of operation is as follows:

When the ovens are newly built they are first heated either by wood or coke firing in the ovens themselves, or by means of gas supplied from some other source. Very great care is necessarily exercised in heating the great mass of brickwork to a proper coking temperature, the purpose being to avoid too rapid expansion, which would be likely to distort the alignment of the ovens or produce cracks or joints through

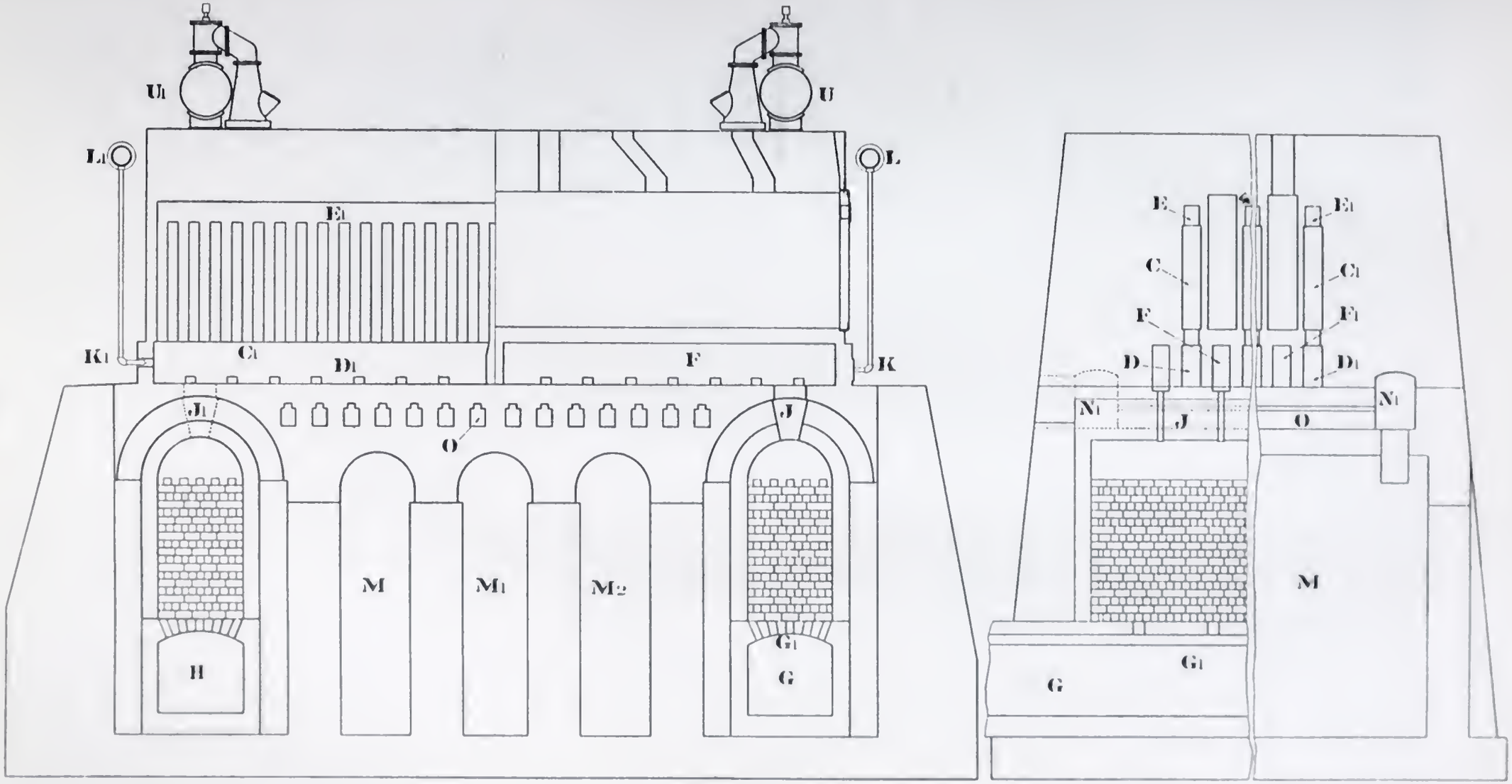
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Fig. 1.

which the gas would leak from the ovens into the flues, or *vice versa*, either case being detrimental to the economical operation of the ovens. The heating process having been concluded, coal is charged into the ovens according to a regular schedule, great care being exercised not to charge too rapidly, in order to avoid the chilling or cooling off of the primary heats. As quickly as the gas commences to properly evolve from the coal it is conveyed through the standpipes and drop valves connecting the ovens into the collecting mains, indicated by the letter U, which are utilized for conveying the gas to the condensing house. It will be observed that this drawing shows two collecting mains, one for the rich gas, the other for the poor gas, which will be explained in greater detail later on, inasmuch as we are now confining ourselves to the method of heating and operating the ovens. The rich or surplus gas is used for illuminating or other purposes; the poor gas is commonly called fuel gas, and is utilized for the continuous heating of the ovens. It is supplied to the ovens through the fuel mains, L, by means of the individual burner pipes, K, alternately. The air of combustion is supplied by being brought from the atmosphere underneath the oven brickwork through the chambers, M, connected at the extreme end of the battery by the cross-header, N, from which it returns through the longitudinal flues, O, being drawn through by a fan and forced into the longitudinal flue, G, underneath the checker-work in the regenerative chamber. In passing from the atmosphere to the regenerators the temperature is increased to about 800° F., and is further increased in passing upward through the regenerative checker-work to 1500 or 1800° F. A port, J, is provided connecting the air-chamber under each oven with the regenerative chamber. The preheated air passing through this port comes in contact with the gas admitted from the fuel line through the burner, K; the principal combustion, therefore, takes place in the chambers provided under each oven, and the materials for further combustion being uniformly distributed from the combustion chamber upward through one-half of the vertical flues into the upper horizontal flue, which conveys it across and down the other half of the vertical flues, thence through the divided portion of the combustion and air-chambers into the regenerator on the other side, where the surplus or off-heat is stored up in the regenerative checker-work. The heating is done alternately. Generally the gas and air are supplied through one-half of the oven for one-half hour and reversed the next half, thus pursuing the process of giving up and restoring the surplus or off-heat and utilizing the same to an increased efficiency in the gas

consumption for heating the ovens. The more carefully this feature of the oven operation is carried out the greater are the results in surplus gas for illuminating or other purposes. The temperature of the off-gas to the stack should not go above 600° F. The heat value of the fuel gas is nominally 550 B. T. U. per cubic foot. The rich or surplus gas usually runs from 700 to 750 B. T. U. The amount of fuel gas consumed per ton of coal varies from 50 to 60 per cent. of the total volume of gas driven off. The amount of gas per ton of coal nominally averages from 9000 to 10,000 cubic feet, depending, of course, upon the character of coal used.

This will be more fully dealt with, subsequently, in connection with the general description of a complete plant. This drawing will serve to demonstrate the seriousness of the problem undertaken in connection with the plant of the Cambria Steel Company, when it is known that the coal to be used by them in this type of oven, as we have previously stated, will swell during the process of coking to such an extent as to raise the tops from the ovens and push the doors out on each end, though solidly clamped with steel bars, unless sufficient space is permitted to remain between the top of the oven and the top of the coal charge to allow of this expansion. Furthermore, the force is so great that, unless care is exercised in charging and pushing the ovens in proper sequence, the side walls will be destorted and thrown seriously out of alignment, thus rendering them very difficult to discharge. The oven-wall construction employed in the Otto-Hoffman oven is believed to be the only type of construction which will withstand, with any degree of satisfaction and long life of service, the requirements of this coal. The character of coal to be used is a very important feature to be considered in connection with the determination of the building of any by-product coke oven plant, as we have discovered from time to time, by exhaustive tests made, the same element of detriment in various other *low volatile coals* which otherwise possess excellent coking qualities.

Following the installation of the plant of the Cambria Steel Company it was deemed necessary by the officials of the United Coke and Gas Company, in order to more generally and practically demonstrate the possibilities of the by-product coke ovens with special reference to the production of metallurgical coke, to install a plant of sufficient producing capacity to supply the requirements of an ordinary sized blast furnace. A site was accordingly selected at Glassport, adjoining McKeesport, near Pittsburgh, as being centrally and most suitably located to

engage the attention of blast furnace managers in the Pittsburgh district, and at the same time be convenient to various blast furnaces which could readily be supplied from this plant, as well as enjoy the advantages of a suitable coal supply; also to permit the sending of various coals from various fields by interested parties to have it coked, and enable them to use the same for trial purposes in their furnaces. In addition, an experimental laboratory and test ovens were arranged for the trying out and testing of coals in carload lots. One hundred and twenty ovens, each 33 feet long, having a coal charging capacity of about six tons, arranged in four batteries of 30 ovens each, were installed, together with a complete by-product plant.

A special feature was introduced in connection with this plant, consisting of the separation of the rich and poor fractions of the gas evolved from the coal; hence the rich and poor mains, previously alluded to, were provided. During the first period—from twelve to thirteen hours—of the coking process the gas from the coal is conveyed into the rich main by means of the standpipes and drop valves, and for the balance of the period is turned into the poor main. The rich gas being much higher in heating value, and very high in illuminants, made a gas of excellent quality for illuminating purposes. This was regarded as a very important step in the development of the industry and was accordingly carefully protected by letters patent, the wisdom of which will be very apparent in our later remarks. This feature involves the direct separation of the two qualities of gas during the entire treatment throughout the condensing-house, up to and including the process of extraction of the ammonia, and further processes to be brought out later. This plant was placed in successful operation and has been maintained continuously with particular reference to the purpose of its original installation, various contracts being made from time to time with parties who use the product for testing the coke value, and for exploitation and development purposes along other lines.

The marked success of the illuminating gas feature developed in connection with the operation of the Glassport plant, coupled with the discovery of the Dominion coal-fields at Cape Breton, Nova Scotia, early in 1896, and the low price at which the coal could be laid down in Boston, and also governed by the fact that the coal produced was of good coking quality and highly volatile, therefore containing large yields of tar and ammonia, prompted the organization of the New England Gas and Coke Company, which was duly organized for the purpose of installing a large plant consisting of 400 ovens, which

would convert, nominally, 2000 to 2500 tons of coal per day into coke for supplying the New England market, particularly the railroads, with a smokeless fuel, and the city of Boston with an excellent domestic fuel. In addition thereto, the city of Boston and the outlying districts could be supplied with the surplus gas which had proved to be of excellent quality.

A ready market was available for utilizing all of the tar and ammonia which could be produced. This plant has been regularly and very successfully operated, and its introduction into the Boston community has figured very prominently and notoriously in the gas wars which have prevailed there during a number of years past. This fact has been brought out conspicuously in the voluminous writings of Lawson. It has been unfortunate, to say the least, that a plant which in itself has so worthily fulfilled every legitimate expectation intended by its original promoters should be depreciated in any way by the mesalliance of various warring corporations. It is worthy of comment, however, that the results have been such as to warrant the confident expectancy that in the not distant future the demands of the community for increased fuel and gas service will require the enlargement of the plant.

As the 400-oven plant of the New England Gas and Coke Company was nearing completion a contract was entered into for the construction of a plant of 400 ovens for the Dominion Iron and Steel Company, at Sydney, Cape Breton, Nova Scotia, for the production of coke to be made from the Dominion coal for use in the modern blast furnaces which they built. The gas at this plant is consumed entirely for fuel purposes, mostly for heating open-hearth furnaces and firing the boilers. In combination with this is a very complete coal-washing plant for the reduction of the sulphur, and, in addition, the English syndicate which has contracted for the tar has installed a plant for its distillation and treatment.

Prior to the completion of the Sydney plant the Hamilton-Otto Coke Company, of Hamilton, Ohio, was organized and contracted for a plant of 50 ovens, arranged with rich and poor systems for the treatment of gas for illuminating and fuel purposes. The promoters of the enterprise were alive to the advantages of the local situation as affording a new field for the disposition of the coke output for foundry purposes, when properly selected, and the residue advantageously converted into domestic sizes. The market was ripe for the use of so excellent a substitute for anthracite coal, much superior to the ordinary gas-house coke, to say nothing of the great benefits which could be derived by the

community from being able to abandon the use of soft coal as a domestic fuel.

Notwithstanding the fact that the city of Hamilton operates a municipal gas plant, a franchise was obtained and the gas from the coke oven plant was introduced with such pronounced success that, solely because of the superior quality of the gas, we are reliably informed it has resulted in the municipal plant being almost obliged to abandon its business.

Doubtless all present are familiar to some extent with the affairs of the Lackawanna Steel Company, with particular reference to the gigantic plant which was planned, built, and put in operation at Buffalo during the past five years, as well as the leasing and operation of blast furnaces in the Lebanon Valley district. It was only natural, in the planning of such enormous plants, that they should incorporate the most advanced methods for the production of material and completion of product tending to the reduction of cost and rapidly increasing output which the most industrious research, careful investigations and advanced engineering skill should suggest. This was undoubtedly the very earnest desire of the promoters and financial interests. Surely one of the most important means tributary to the fulfillment of this expectation was the coke supply. Knowledge of the excellent character of the coke obtained by the Cambria Steel Company led them, when an opportuntity offered, to purchase a large tract of what was believed to be similar coal, and they proceeded to open and equip mines. Samples of the coal were taken and exhaustive coking tests made at the Glassport plant, under the direct supervision of the superintendent and his associates of their coke oven department. The results were made the basis of a report substantiating the fact that the coal was of good coking quality, though high in sulphur, which would require washing, but so low in volatile as to make it worth considering only in connection with by-product coke ovens. The outcome was a contract made with the United Coke and Gas Company for licenses for two plants, one of 232 ovens to be located at Lebanon, Pa., and one plant at Buffalo, N. Y., of 564 ovens, with a combined coke producing capacity of about three thousand eight hundred net tons per day of twenty-four hours. The working of the coal property unfortunately proved unsatisfactory, and a combination of conditions in connection with the general affairs of the company, growing out of a change of the executive heads and management, compelled a suspension of the mining properties, and, consequently, of the coke oven department;

but the Lebanon and Buffalo coke plants have again been put in operation, arrangements having been made for coal suited to their needs. Foundations are completed and coal-handling facilities are provided at the Buffalo plant for the installation of 1128 ovens, making, when completed, by great odds the largest by-product coke plant in the world, capable of carbonizing at least 6500 net tons of coal per day.

A description of the first half of the Buffalo plant, consisting of 564 ovens, will follow later.

Thus we conclude what may be appropriately regarded as the past era of the by-product ovens of the Otto-Hoffman type. During this period the Semet-Solvay Company erected plants at Dunbar, Pa., Sharon, Pa., Wheeling, W. Va., Ensley, Ala., and Detroit, Mich., all except the Detroit plant being for blast furnace coke. The Detroit plant was built by the Solvay Process Company for its own ammonia needs, the coke being used for foundry, furnace, and domestic purposes.

Despite the numerous obstacles encountered, both engineering and commercial, the jeers of skeptics, the sneers of critics, the doubting Thomases, the cold-water and wet-blanket crowds, such as are ever ready to thwart the purposes of progress, this industry has made such rapid strides that it has come abreast of the spirit of the present time, and during recent years has commanded the recognition of engineers in both the metallurgical and gas manufacturing departments of our schools of progress, arresting the considerate attention of the "captains of industry."

In taking up what we have elected to group under the present era of this subject, we shall endeavor to present the reasons for calling attention to the metallurgical and gas manufacturing departments. It is frequently charged by the blast furnace and foundry men that coke made in by-product ovens is inferior because of the utilization of the by-products, and the gas man charges that it is too expensive a method of obtaining gas, and furthermore that the quality of the gas is not comparable with the advanced methods of gas manufacture, because the character of the coal used is not suited for gas manufacture on account of the necessity for using such coal as will produce coke of suitable structure for blast furnace, foundry, or other needs.

To show the utter erroneousness of such charges, though we do not question the good faith in which they are made—they simply result from a misconception of the facts, due principally to lack of knowledge—we shall briefly outline the complete arrangement and operation of a plant, showing the distinct line of demarcation between the actual manufacture of coke and the treatment of the gas and by-products.

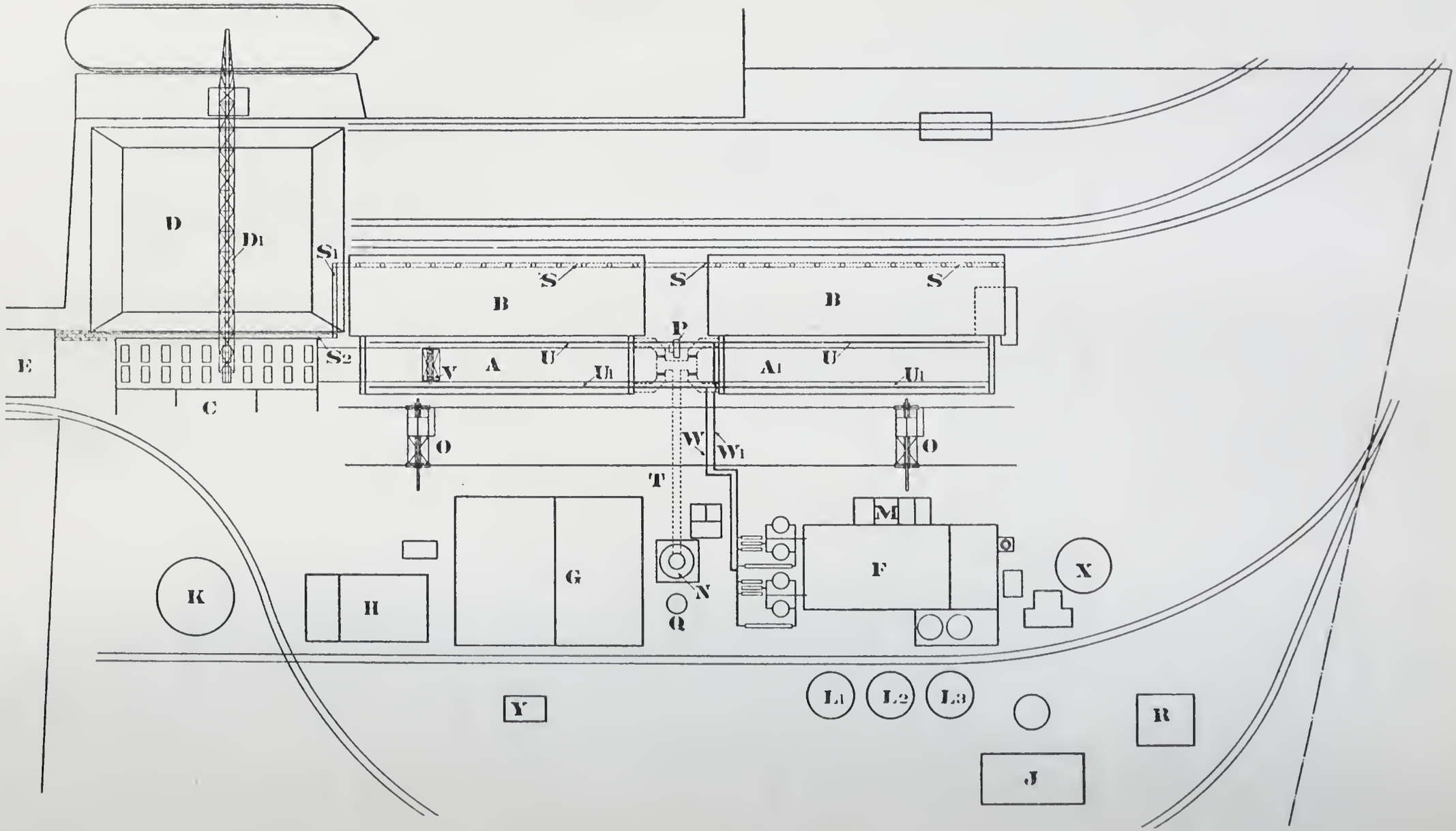


Fig. 2.

Fig. 2 shows the general arrangement of a plant of 100 ovens which has been installed at Camden, N. J. Coal is received by either boat or rail. On the drawing is indicated the coal-storage pile from which coal is taken in the event of an emergency preventing them from getting the regular daily supply for keeping the elevated coal bin filled for the regular continuous operation of the plant. A plant of 100 ovens is usually divided into two batteries of 50 ovens each. The batteries and platforms upon which the coke is pushed are shown on this drawing and lettered A and B, respectively; the mechanical pushers for discharging the coke are lettered O; the building containing the condensing apparatus and equipment is lettered F, the power-house is marked G, having arranged therein an electrical power equipment for generating the current for the entire plant and lighting system; ammonia house is marked H, and is equipped with a complete system for the recovery of the ammonia which has been given up into the ammoniacal liquor during the condensing process; the large tank for the storage of from sixty to ninety days of tar is marked K; X, the auxiliary gas holder, or, practically speaking, the governor for the fuel supply to the ovens; tanks marked L are for the storage of ammoniacal liquor; Y indicates the laboratory; J, the benzol house, containing the equipment for the recovery of the benzol, and R the general offices. The space occupied by the plant as indicated is approximately 500 by 1000 feet.

The contrast between the older method of arranging a plant, where the coke is pushed on to platforms and handled into cars purely by hand labor, and the later improved methods which have been adopted and put into use in connection with some of the more recent plant is very marked. The advantages of the labor-saving devices become instantly apparent. In the former plant the coal is taken from the supply bin and discharged into the ovens by the use of a charging larry, arranged with spouts covering each charging hole as shown. It was formerly the custom to mount above the ovens a substantial bridge structure, spanning entirely each oven battery, while in the later plants the bridge is dispensed with and the oven battery itself is utilized by having mounted thereon suitable steel or cast-iron girders, with track facilities for conveying the larry from oven to oven as desired. The method of unloading the coal from cars or boat, as the case may be, has been materially simplified and the supply bin is, we believe, arranged to better advantage by locating the same between the batteries instead of arranging them at the end of two or more batteries.

The substructure supporting the ovens has been materially improved by mounting the ovens proper upon steel beam-work arranged upon three longitudinal walls of concrete construction as shown. The regenerators have been placed in substantially the same position as heretofore with reference to the oven arrangement, but the serious objection of having them perform, in addition to the regenerative service, the function of a main support to the ovens proper, has been eliminated. The contraction and expansion constantly going on in the oven brick-work as well as the regenerators make the advantages of this feature very apparent. The pushing device for discharging the ovens is substantially the same as has been in vogue for years, with the exception that in order to increase the output, due materially to the more rapid coking in the ovens, it has been found necessary to vastly strengthen all of the parts.

Another material improvement which has been of great service in maintaining the uniformity of charge, insuring practically the same amount of coal being supplied to each oven, has been the mechanical leveling device, which is mounted upon the pusher and operated by the same attendant. In combination therewith is a further labor-saving arrangement, on the more recent plants, consisting of a door-hoisting device so arranged as to be operated also by the pusher-man. This is a very simple and inexpensive contrivance, and very effective both as to minimizing time and reducing the expense of labor and repairs. The method of handling the doors in vogue prior to the past few years has been to operate them by a hand-winch arranged on tracks running longitudinally with the ovens, and requiring generally the services of two men to each side of the battery, because the doors on the ovens are handled practically simultaneously. The sequence of each of these devices makes the arrangement such that there is ample time for the performance of each function. When the doors are removed from an oven, which is only done when it is ready to be pushed, the pusher-ram discharges the oven on to a coke platform, while in the other arrangement it is discharged into a coke-quenching machine, which is a device made large enough to receive the entire charge of the oven practically unbroken. The general arrangement of the machine is such as to permit its being operated similarly in its travel from end to end of the oven batteries to the coke-pushing machine, and it follows that when the oven is to be pushed the pusher must be ready at the oven simultaneously with the quenching machine. When the oven is pushed the doors of the quenching machine are closed and the quenching process is

proceeded with by an arrangement of a water-supply trench in combination with a motor-driven rotary pump which discharges the water into the cast-iron water-jacketed box in which the coke has been placed, and this in turn overflows throughout the entire length of the box at an elevation higher than the top of the coke, causing the same to be instantaneously deluged with the quantity of water which is found to be sufficient for the quenching needs of the coke charged. In addition to the water being supplied through the water-jacketed sections the cast-iron box is prevented from cracking and is constantly kept supplied with fresh cold water. After the coke is quenched it is discharged into the cars which are immediately available on the coke-loading tracks, either by spreading it into several cars or into a single car, at the option of the operator, for he has entire control of the traction traverse, as well as control of the movable bottom arranged in combination with the machine which discharges the coke into the car. The advantages of this machine with reference to the time element as well as labor economy are so readily apparent as to require no further comment.

It can be readily seen that all of the essentials are embodied in this arrangement for the complete production of coke, irrespective of the by-product installation of the plant, with the exception, of course, of the gas required for heating the ovens. This heat is indirectly applied, as previously explained in describing the rotation of the heating process. It only remains for you to realize that the difference between the ordinary beehive method and the by-product method, so called, consists in the fact that in the beehive process the heat is supplied by the combustion and partial consumption of the coal bed itself during the coking period, the air of combustion being admitted through the single door provided for withdrawing the coke. The only other point of difference existing is where the gas is released from the oven. In the case of the beehive oven it passes through the charging hole in the top of the oven and out to the atmosphere. This practice would be maintained in the by-product oven simply by removing the standpipes connecting each oven with the collecting mains heretofore referred to, or, more simply still, by closing the valve connecting the same and removing the lid at the top of the standpipe connection, thus permitting the gas in the same manner to pass off into the atmosphere to be wasted, and what this waste means will be shown later in actual figures.

A coke-producing plant of this type is therefore absolutely independent of any by-product equipment. Indeed, there have been installed at

various periods in Europe plants of this type, so arranged that the gas is immediately consumed when evolved from the coal by being taken into the flues and burned on its passage downward from the ovens, thus eliminating all expense whatsoever of the by-product end of the plant. The error of this arrangement, however, has proved itself to be very disastrous from a financial point of view, and it is not considered in connection with plants installed in recent years, although the non-by-product method, in contrast with beehive coke, possesses all the advantages from a labor-saving point of view which have been pointed out, besides an increased output of coke per ton of coal used.

The gas passing from the coal being converted into coke is worth from eighty cents to one dollar or more per ton when properly treated and separated. When the gas is properly utilized it is convertible into heat, which represents work, or other uses of high commercial value, and it is not sane judgment to permit the passage into the atmosphere of such an enormous volume of excellent revenue-producing material, to say nothing of the disadvantages incident to the contamination of the atmosphere, the destructive influences upon surrounding vegetation, and the unhealthy condition created throughout the community at large. Attention, therefore, is invited to a description of the means employed for the treatment of the gas conveyed through the mains upon the tops of the oven batteries from the coal carbonized.

A complete plant, installed in connection with the coke ovens built by the Lackawanna Steel Company, at Buffalo, N. Y., condensed under one roof with equipment sufficient for the handling of forty million feet of gas per day, will serve to demonstrate to the gas manufacturing department the applicability of this feature of the by-product coke oven industry. A large gas conveying main, running longitudinally with the main building, carries the gas supply from the ovens to the condensing-house.

The first series of apparatus for the treatment of the gas are patented air- and water-coolers, the function of which is to regularly reduce the temperature of the gas, without shock from too rapid chilling, from the inlet temperature, which is probably from 300 to 150° F. This is effectually produced by water spray applied at the top of each section and permitted to flow in thin sheets on the outside and down both sides of the rectangular sections, passing from one to the other in contra direction to the gas. The water being exposed to the air gives off the heat in its passage down and over the surface, and thereby reduces to a great extent the quantity of water required for the reduction of the

temperature in this pass. Furthermore, the uniformity of reduction is maintained by increasing or diminishing the supply of water to an exact nicety with the requirements of each individual section, and for several months in the year the exposed surface of the coolers is alone sufficient, thereby eliminating the use of the water entirely. The temperature is controlled by increasing or diminishing the volume of gas passing through each bank of coolers. The second apparatus is for further reduction of the temperature from 150° to nominally 75 or 80°, and is a patented 9-pass multitubular cooler, the gas passing alternately up and down through the tubes around which water is circulated, also passing alternately up and down but in opposite direction to the flow of the gas. This type of apparatus is also very effective because of the delicacy with which the regulation may be controlled, permitting the tarry vapors to be properly condensed, thrown down and removed from the apparatus at each successive stage of the condensing period. Effort is made by the treatment of the gas through this apparatus to remove practically all of the tar and lighter oils. This, however, is not accomplished to the extent desired, and it has, therefore, by experience been found necessary to arrange an apparatus in such series on what is termed the pressure side of the house, to finally extract the tar. The foregoing condensing apparatus is worked in this system under slight suction, the gas being drawn through the supply mains from the ovens and through the forward apparatus by means of direct connected steam driven rotary exhausters. The regulation of this suction is controlled in such manner as to take the gas from the ovens when they are operating under very slight internal pressure. A simple mechanical governing device has been invented and introduced, with splendid success, enabling this feature of the oven operation to be carried out to good practical advantage. From the exhausters the gas is discharged through the final tar extractors into the ammonia scrubbing apparatus, which consists in this case of a series of triple-tower scrubbers, each apparatus comprising three distinct towers, combined to permit the gas to pass upward in each case through an arrangement of wooden slats, over which from top to bottom is trickled a uniform supply of water or ammoniacal liquor, of variable strength as may be required for the proper absorption of the ammonia from the gas, which has been previously cleansed from the heavier tarry substances. Fresh water and ammoniacal liquor are circulated through these scrubbers until the desired strength is secured, when it is discharged by a pump into the ammoniacal storage tanks outside of the building. From these tanks

it is taken and the ammonia distilled by special distilling apparatus which evaporates the water, liberating the ammonia vapors, which are in turn condensed into the form of concentrated ammonia, or otherwise converted into sulphate of ammonia. This plant is arranged for the production of ammonia in either form. On account of the vast quantities produced, however, and the more advantageous price to be obtained for sulphate of ammonia, most plants are now manufacturing sulphate for the general fertilizing market trade.

In addition to the extraction of ammonia it has recently been found very practicable and profitable to install scrubbing and other apparatus for the extraction of the benzol carried in the fuel gas. This has been performed very successfully at the Camden plant during the past year, and advantageously utilized for increasing the candle power of the gas. In the event of it becoming necessary to utilize surplus gas in any locality for fuel purposes only, a complete benzol extraction plant can be installed at nominal cost, and important revenue derived from its sale for gas enrichment purposes in lieu of the usual enriching oil now generally used.

These by-products, as produced at the by-product coke oven plants, operated by whatever system, are practically controlled, so far as their sales are concerned, by the American Coal Products Company, 17 Battery Place, New York City, who are virtually the distributors of this material to all branches of the chemical trades, who utilize them by further refinement for the many uses to which they are applied.

The establishment of plants in various localities throughout the country during the past few years has been the means of demonstrating their practicability for various uses. The United Coke and Gas Company installed in Camden during the second period under consideration a plant of 100 ovens for the Public Service Corporation of New Jersey, the coke produced being converted into various sizes, sold almost exclusively for domestic consumption, and marketed in the same manner as anthracite coal. A portion of the output, however, is sold for foundry purposes, the principal customer in this line being the Baldwin Locomotive Works. The gas is used for illuminating purposes, lighting the cities of Camden and Trenton and the intermediate towns between Camden, Trenton and Woodbury, N. J. Also a plant of 200 ovens, each with a charging capacity of nine net tons of coal, for the Maryland Steel Company, Sparrows Point, Md., the coke made by these ovens being used in the blast furnaces of the company at Sparrows Point. The surplus gas is sent to Baltimore where it is used for

lighting the city; a plant of 15 ovens, of the nine-ton charging capacity, at Wyandotte, Mich., for the Michigan Alkali Company, the coke being used in the lime-kilns required by them in connection with their soda ash works, and the surplus gas used for the heating of some special furnaces in their process department; a plant of 212 ovens, with nine-ton charging capacity, for the Sharon Coke Company, Sharon, Pa., the coke being used for the blast furnaces located upon the same property, and the gas being utilized for heating purposes in the various mills, being a part of the combined plant; a plant of 50 ovens of seven-ton capacity each for the Zenith Furnace Company, Duluth, Minn., the coke being used in their furnace immediately adjacent to the coke plant, and the gas sold to the city for illuminating purposes.

During the same period the Semet-Solvay Company has installed a plant of 40 ovens at Chester, Pa., intending to supply coke to the Tidewater Steel Company; a plant of 80 ovens at Milwaukee, where the coke is used for domestic and foundry purposes, and the gas supplied to the city; a plant of 90 ovens at Lebanon, in combination with the Coleman furnaces, an allied interest of the Pennsylvania Steel Company, the coke being used in the furnaces, and the surplus gas supplied to the American Iron and Steel Manufacturing Company; a plant of 30 ovens at Geneva, N. Y., the coke being sold in the community and the gas disposed of locally.

Installations of each of the United Coke and Gas Company's types of ovens now building are:—112 ovens, being the fourth installation, completing a plant of 372 ovens for the Cambria Steel Company, at Johnstown, Pa.; 50 ovens of the most modern type being added to the Camden plant, and a duplication of the 15 ovens installed at Wyandotte, Mich., for the Michigan Alkali Company.

The Semet-Solvay Company has also secured contracts for 120 ovens for the Pennsylvania Steel Company, at Steelton, Pa., and has built a plant of 120 ovens in the city of Chicago on their own account for the purpose of supplying coke locally, the gas to be disposed of, as reported, to the city.

The repeat contracts which have been entered into during the year are in themselves sufficient evidence of the success attained by the previously installed plants, and have undoubtedly been the means of establishing a great deal of confidence as to the future outcome of the industry among large interests, entirely lifting the plane of consideration beyond the prejudice of those who have been accustomed to look upon the so-called "isolated ventures" as dreams of enthusiasts.

Although it has not been intended as within the scope of this paper to introduce much statistical data the following figures will probably be of interest, since they furnish substantial evidence of the superior merits and advantages of by-product ovens over beehive ovens, and give important information bearing upon the future prospects of this industry in its various ramifications.

An example has been taken of an average sized plant of 100 by-product ovens, each with a charging capacity of 7½ net tons of coal, equal to 750 net tons to be carbonized daily. Comparison is established by figures showing the net cost per ton in ordinary beehive ovens and in by-product ovens on the same basis of coal carbonized. The cost of the coal at the mines has been taken at $1 per net ton in each case. The item of freight has been ignored, as the freight on coal is taken to offset the freight on the coke, although the average cost of coke transportation generally is higher than that of coal, on account of the greater bulk of coke. By reference to the statement it will be seen that the cost for 750 tons of coal used in beehive ovens at $1 is $750 per day; the labor, repairs, and all other capital charges per ton of coal carbonized, taken at 50 cents, is $375, making a total of $1125. The coke output on a basis of 65 per cent. yield would be 487½ net tons of coke, making cost thereof per net ton of coke, $2.30. By the statement showing results from the by-product ovens we have under expense, 750 net tons of coal at $1, $750; labor, repairs, and all other capital charges per ton of coal carbonized, 80 cents, the capital charge being materially increased on account of the greater cost of the plant, making $600, a total cost of coal and other expenses of $1350. The credits for by-product returns, covering ammonia, tar, benzol, and the surplus gas sold at fuel value, aggregate $1003.55, leaving a balance of $346.45 representing the cost of coke produced, which in the case of by-product ovens is 75 per cent., a total of 562½ net tons of coke, the cost of which upon this pasis is 61.6 cents per net ton; or, by substituting 25 cents per thousand cubic feet of gas sold for illuminating purposes instead of for fuel purposes, as credited in the above statement, the total credit for the daily output would be $1336.80, showing a difference between the combined cost of the coal and labor of $13.20, or making the actual cost per net ton of coke 2.35 cents. In other words, if the gas be sold at 10 cents per thousand feet for fuel purposes, the beehive coke will cost $1.684 more than the by-product coke, and if the gas is sold for 25 cents per thousand feet for illuminating purposes, the coke from beehive ovens will cost $2.2765 more per net ton.

The figures used in the preparation of these statements for by-product ovens are based upon actual results, and so far as we are able to learn from information obtained the figures given covering the labor and other expenses in connection with the beehive oven results are conservative, and the coke yield given is perhaps higher than is obtained in the general practice.

The present capacity of the ovens contracted for under licenses of the United Coke and Gas Company is 5,200,000 tons, and those contracted for by the Semet-Solvay Company 2,800,000 net tons of coal, producing in total 6,000,000 tons of coke on the basis of 75 per cent. output, although some of the plants, notably that of the Cambria Steel Company, get a considerably larger yield on account of their low volatile coal. Accepting the figures given in reliable trade reports, the entire production of coke for the year 1905 was over 26,000,000 tons; therefore, about 23 per cent. of the entire quantity of coke produced in this country is from by-product ovens.

PLANT OF 100 OVENS, EACH WITH A CHARGING CAPACITY OF 7½ TONS=750 TONS OF COAL DAILY.

(The item of freight is ignored as the coke would offset the coal in either case.)

BEEHIVE OVENS—DAILY RESULTS.

Expenses.

750 net tons coal cost at mines, $1	$750.00
Labor, repairs, and all capital charges per ton of coal carbonized, @ 50c.	375.00
	$1125.00

Coke Output.

Coal yielding 65% coke=487.50 net tons coke	
Cost per net ton coke	$2.50

BY-PRODUCT OVENS—DAILY RESULTS.

Expenses.

750 net tons coal cost at mines $1		$750.00
Labor, repairs and all capital charges per ton of coal carbonized @ 80c.		600.00
		$1350.00

By-product Returns (actual results).

Ammonia, NH_3=3900 @ 8.5c.	$331.50	
Tar, 7627.50 gals. @ 1.8c.	137.30	
Benzol, less production cost	187.50	
Gas, 3,472,000 @ fuel value of 10c. per 1000 cu. ft.	347.25	$1003.55
		$346.45

Coke Output.

Coal yielding 75% coke = 562.50 net tons coke.		
Cost per net ton coke		$0.61 $\frac{8}{10}$
Or, substituting 25c. per 1000 cu. ft. for gas sold for illuminating purposes we have,—		
Ammonia	$331.50	
Tar,	137.30 (above cost)	$1350.00
Gas, 3,472,000 @ 25 c. per 1000 cu. ft.	868.00	1336.80
		$13.20
Cost per net ton coke		$0.02 $\frac{35}{100}$

From the experiences of the past we learn lessons which give wisdom for judgment as to the possibilities of the future. We of the present doubtless vividly recall the experiences in the early days of the in-

troduction of the electric light and the telephone (marvellous to all then, small application then, commonplace today). What would have been thought of those who dared prophesy as to the most wonderful developments in the realm of electricity since that time, with its thousands of additional applications! What must be the feelings of some of our Philadelphia editors and newspaper correspondents if they ever look over their files and read the predictions as to all the direful things which would follow the introduction of trolley cars into Philadelphia! They said they were "all right for isolated, out of the way places," but "not suitable to congested districts." So we could go on through an endless chain of instances, throughout every branch of industry turned by the wheels of progress, at every turn finding abundant reasons for deep gratitude for the everlasting efforts of the various engineering fraternities in developing all these vast benefits provided by God in nature, foreordered and prearranged by the Creator to be brought into line, timed to the needs of the world as indicated by the great clock of the universe!

Therefore, in regard to the future of the coking and gas industries, upon the basis of the statements just presented and the position now occupied, are we not justified in prophesying that when the American manufacturers and financiers become fully alive to the possibilities before them for economy and enormous returns, the business must necessarily expand in keeping with the other gigantic enterprises created by necessity and promoted by progress, which have produced the world-renowned American Captains of Industry, perhaps slowly in initial movement, but when fully aroused exerting powerful energy, giving such stupendous momentum as will speedily make the manufacture of coke by the antiquated methods of the beehive process so obsolete that the coming generation will look upon the beehive ovens—if any remain to tell the tale of bygone extravagance—as unique as well as antique?

DISCUSSION.

Edw. S. Hutchinson.—In the Pocahontas region of West Virginia the coke ovens are nearly all of the beehive pattern and the yield from them varies from 55 to 65 per cent. of the coal coked. A few years ago the Southwest Virginia Improvement Co.—now the Pocahontas Collieries Co.—erected a few by-product ovens. I have not seen them since they were finished—six or seven years ago—and do not know whether they have been successful.

Some years ago we sent several cars of Pocahontas coal to Syracuse, N. Y., to be coked in the by-product ovens as an experiment, and my recollection is that 82 to 85 per cent. was obtained. We realized, of course, that the beehive oven

was wasteful, but the conditions obtaining decided us to continue their use. The population of the district was scattered along the railroad for about twenty miles and there being no mills nor factories nor furnaces we would have had little use for gas. Furthermore the percentage of volatile carbon in this coal is only 18 to 20. The problem was very different from what it was in Pennsylvania and along the Baltimore and Ohio Railroad, where the volatile carbon per cent. runs from 33 to 38. Then, too, by-product ovens were very costly and we figured that under the prevailing conditions the great outlay required to instal them was hardly warranted. Since that time, however, the conditions have materially changed.

F. E. Dodge.—I believe that the ovens that Mr. Hutchinson speaks of were not the regular by-product ovens; they were modified beehive ovens. In these ovens the coal is coked at a lower temperature than in the ordinary by-product ovens. Some of the by-products from the ovens of the Southwestern Improvement Co. have come under my notice and they are quite different from the by-products of the Otto-Hoffman or Semet-Solvay ovens and seem to indicate a lower coking temperature.

Mr. Moore.—Pocahontas coal cannot be coked alone with commercial success. By mixing with it twenty-five or thirty per cent. of other coal we get just the thing that the blast furnace man wants. At the Camden plant we get three different kinds of coal and mix them together and obtain the volatile that we require.

At the Camden plant we have gotten results beyond all expectation. Some people in the gas business thought that it would be impossible to convey gas to Trenton from Camden. During nine months past we have conveyed it thirty-eight miles under a pressure of 12 pounds without a complaint. The average candle-power has been 18.07, and it has run as high as 25. There is no deposit in it. An exhaustive test was made last December when it was expected to have to pump drips. The gentleman who made the test reported, after testing all over the line, that at the rate he was collecting the condensation it would take him four years and eight months to get sufficient to make a sample.

Magnesite brick have been tried in four ovens. The objection to them is their high cost. Formerly we used calorized brick. We use slag brick now and grind them to a uniform thickness, and they work very well. We watch them very carefully but have little or no trouble from expansion. The face fronts are made of No. 1 clay.

Paper No. 1021.

THE NEW SEA-WALL AT ANNAPOLIS, MD.

HARRISON W. LATTA.

Read March 17, 1906.

The scheme for the improvement of the Naval Academy at Annapolis involved the acquisition of property on shore and the reclaiming of land on the Chesapeake Bay front and along the Severn River, the land secured in this way being the area between the old and new sea walls. The old structure was of stone, the foundation resting on original bottom. This was sufficiently solid for this purpose, as there was no depth of water along the sea wall, which was built merely for the protection of the banks.

In carrying out the scheme of improvement it was planned to first construct the new power-house. This building was to be located on a pier extending some 400 feet from the shore line on the Severn River. Mr. Percy H. Wilson, in a paper read before the Club, described the construction, failure, and final saving of this wall. After the disastrous experience with this work sea-wall building at the Naval Academy was looked upon as a serious undertaking, particularly as the new wall connected with the power-house pier wall at two points.

Under these conditions the Government authorities, being dissatisfied with the last contract, decided to build the wall by day labor, and with this end in view purchased the necessary lumber, stone, cement, etc. However, before the actual operations were started there was a change of heart, and contract work was decided upon.

Plans were prepared for a wall supported on piers spanned by concrete arches, the work to be divided into six sections. Back of the wall were reinforced concrete arches spanning the same piers and relieving the wall from the thrust of the back filling, holding this back filling so that the toe of the slope came within the line of the wall. This work was advertised, the Government agreeing to furnish such materials as it had purchased, which would be available for the construction. The bids were received on the different sections of the wall. Section I A was of simple construction, being designed as a retaining wall, there being but three feet depth of water in front of it. The total of the lowest bid was very largely in excess of the appropriation, but on the

I A section the bids were close and that particular portion of the work was awarded at that time—June, 1903.

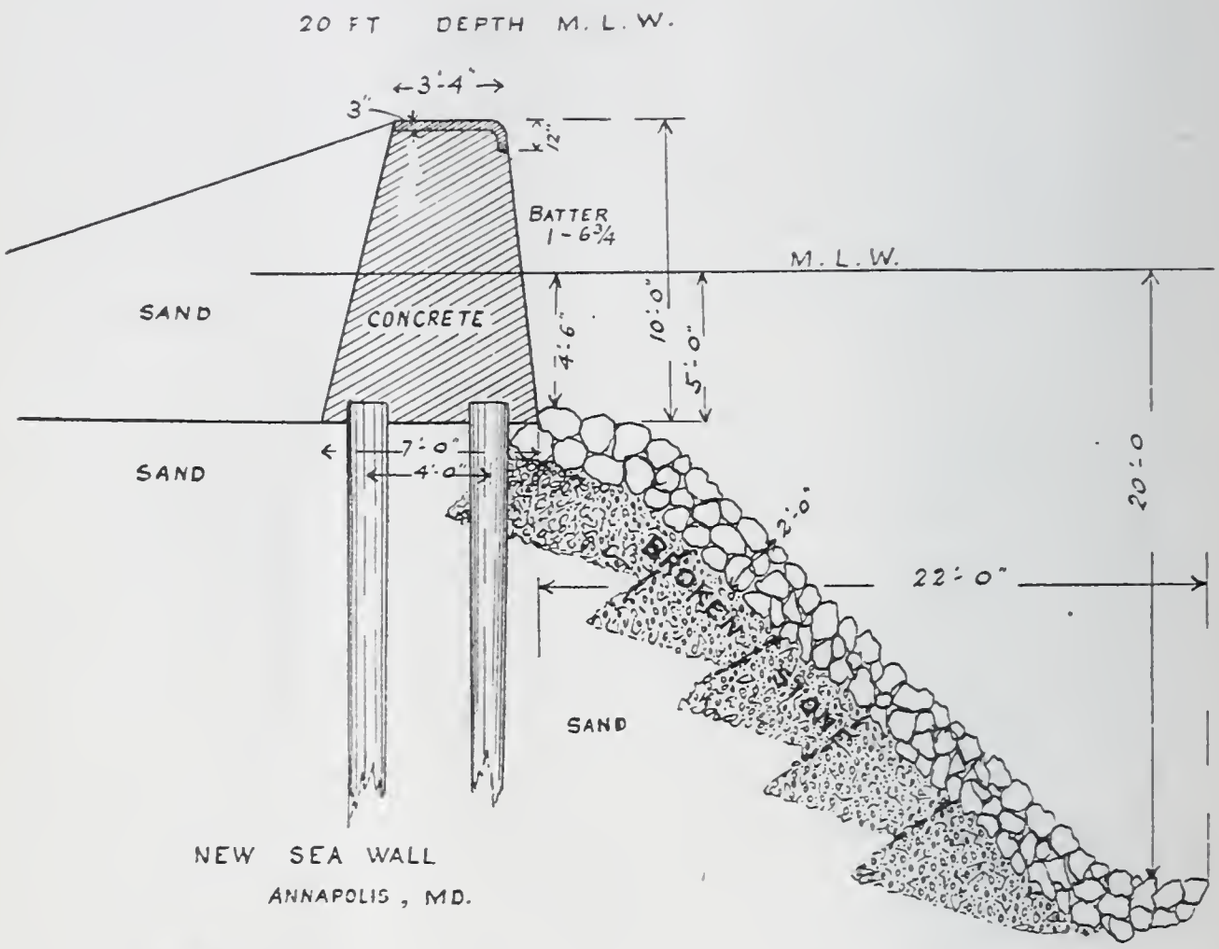
It was now necessary to make a new and more economical design, keeping in view the use of the materials already purchased for this work. The result was a concrete wall built directly on the piles, without the necessity of any cribbing or caisson work. As this wall extended only five feet below water, the required depth of water—20 feet—was secured by a riprap slope in front of the wall. On this design of wall the prices bid came within the appropriation and this work was awarded in July. However, the "law's delays" came in here, and a discussion as to whether the contract should be signed by the Chief of the Bureau of Navigation or by the Secretary of the Navy held up the contract until October. A special plant was required for the work, and the season was now so far advanced that nothing could be done except pile-driving and some of the filling until the weather opened up the next spring.

During that winter, however, the work of the construction of the plant was carried on. First, the concrete mixing scow was built. This was 80 feet long, 23 feet wide, and 8 feet deep. In the center was mounted a Hains mixer, and on each end a derrick—one to handle the materials and the other the concrete, which it placed in the wall. Another scow was built—56x23x4 feet—on one end of which was mounted a circular saw on a vertical shaft for cutting off piles under water. On the other end of the same scow was a derrick to be used in placing and removing the forms. A third scow for water and hauling materials for the construction was the last one built. There were also built chutes for placing riprap, forms for concrete, etc.

The fill back of the wall was first made by scowing in dredged sand to an elevation of about —6. When this fill had been made out to the line of the wall the piles were driven. Using these piles as a guide the crushed stone and large riprap were placed, a dredge first excavating to the proper depth in front of the wall.

The scow on which the riprap was delivered was laid broadside to the piles, held off at the proper distance by wooden frames. Between the scow and the piles was placed a wooden chute 40 feet long, 5 feet wide and 5 feet deep. The opening in the chute was 2 feet wide and ran nearly the entire length. The stone was dropped through this opening, until soundings taken through the chute showed the riprap had been brought up to the proper elevation,—the position of the chute being known, the correct elevation for the riprap could be determined.

When this proper elevation had been reached the scow and chute were moved in four feet, and this operation was repeated until the crushed stone had been brought up to the line of the piles. The large riprap stone was then placed in the same manner. The piles were then cut off 4½ feet below water with the circular saw mounted on a vertical shaft. The work was now ready for the placing of the concrete.



The forms were built in 12-foot sections, fastened together at the top with a cap-piece and at the bottom by a wire to keep them from spreading, and a brace to hold them apart. By removing the cap-piece and cutting the wire, which was below the water, the two sides came off and could be used again. The method of procedure was to remove six or eight of these 12-foot forms from the completed wall and place them on a scow, where the two sides were set in an upright position, connected by the cap-piece at the top and braced and tied across the bottom. In this way each 12-foot section of form for the wall was built up. The section of form was raised by the derrick and set down in the water and bolted to the section of form which had not as yet been removed from the completed wall. The form thus placed was

held to the proper elevation by long stakes driven in the sand. The form was then spiked and held in line by braces spiked to the form and to the brace piles driven back of the line of the wall. In this way the several sections of form were placed. Then the sand was filled in back of and between the forms to bring the bottom to the required grade, and in the front the riprap was brought up to the completed grade and filled with small crushed stone against the form to prevent concrete from escaping under the lower edge. The work was now ready for the concrete to be brought up to the water line.

The concrete was mixed and placed as follows: Sand was brought in on small schooners and loaded into bins on the mixing scow after working hours. Stone was delivered on barges holding about 300 cubic yards. These barges were placed alongside the mixer so that the derrick could reach the stone, which was hoisted directly from the scow to the mixer by this derrick. This derrick also hoisted the sand and cement. A Hains mixer was mounted on the middle of the scow. The mixed concrete fell into a bucket placed on a car in the hold of the scow. This car was pushed to a point where the other derrick could reach the bucket. An empty bucket was placed on the car and a full one taken away. The derrick then lifted the bucket of concrete and placed it in between the forms. When the bucket reached the bottom, the opening in the bucket was released and the concrete deposited in place. This process was continued until a section of wall about 60 feet long had been brought to the surface of the water. The following day the planks were placed on the part of the form above the water and the wall brought up to within a foot of its finished height.

When the concrete work was first started it was intended to make the concrete under water continuous; that is, to leave a slope at the end of the wall at night and begin by placing the next day's concrete on this slope. It was found, however, that there was a deposit of magnesia, caused by a reaction between the sea water and cement, which settled on this slope and on the bottom, ahead of the concrete work. As this deposit could not be removed without great difficulty and expense, it was found necessary to place a bulkhead in the forms and end the day's work at that bulkhead. In this way the deposit was forced out from between the forms before it had time to settle, and it was found scattered over the bottom outside the line of the wall where is could do no harm. These bulkheads also furnished expansion joints in the wall, —a sheet of tar paper being placed against the completed work before fresh concrete of the succeeding section was placed against it.

After the wall had been brought up to four feet above M.L.W., the fill back of the wall was completed by dredging material from the front and casting it over back of the wall.

The upper part of the wall, one foot in depth, on which was a granolithic finish, was placed after the back fill had been made, forms being clamped to the wall already built.

What was known as "Section F, G," or the north breakwater, adjoined the wall of the power-house pier, which had been built by another contractor and had failed.

So far as securing a suitable and stable foundation was concerned, this piece of the work was the most difficult of the entire contract. The breakwater was only 110 feet long and 30 feet wide, but it was known that at that location there was a deep deposit of almost liquid mud. To secure a foundation it was necessary to replace this mud with sand. Sand was dredged and brought in to the site of the breakwater on scows and dumped until its weight pushed the mud out into a shoal of mud on either side. These shoals were removed by dredging and the sand settled. More sand was then scowed in and the shoals, which again formed, were dug away. This operation was repeated until almost 20,000 cubic yards of sand had been dumped on the site of the breakwater and a like amount of mud removed. It was then found that the removal of the mud did not result in any further settlement of the sand fill.

The work was now ready for the driving of the piles, and very long ones were required. On the outer end of the breakwater, single sticks—ranging from 70 to 85 feet—were driven. Toward the inner end the bottom was worse and lengths of 100 to 110 feet were required. Single sticks of this length could not be secured and it was found necessary to resort to splicing. After a trial of several methods, the simplest was found to be the best. The first or bottom pile, 60 or 70 feet in length, was driven until the top was within about 3 feet of the water surface. This top was carefully adzed down to a plane surface and trimmed to a diameter of 10 inches. On this was placed a piece of 10 inch wrought-iron pipe 10 inches long. The top pile, the point of which had been carefully trimmed to fit on the pipe, was now raised in the leads and set on the lower pile. The driving was then continued until the required penetration was reached.

On the foundation, constructed in this way, the wall was built, which has not settled in the least, although at the time of the construction the old wall with which it connected was still settling.

DISCUSSION.

Harrison W. Latta (in answer to questions).—In reference to the deposit of magnesia, which occurred during the placing of concrete in the water and during the process of hardening: when dried out this deposit was of the consistency of an impalpable powder and when wet was like a liquid grout of neat cement. It did not harden in the sense of setting, but it became more compact as it settled or was compressed. It would cover the bottom between the forms and would sometimes accumulate to the depth of a foot around the piles, and these being five feet under water, there was considerable difficulty in removing it. By bulkheading, the water holding the magnesia in suspension was forced out from between the forms, and the deposits occurred outside the line of the forms where they could do no harm.

The removal of this magnesia did not in any way affect the properties of the cement. The concrete set up as well as any with which I have had experience. The forms were usually removed in forty-eight hours, but could have been removed in twenty-four.

In beginning the construction, a section of wall 100 feet in length was built before this deposit of magnesia interfered with the work. It was then found to a depth of from 6 to 12 inches and extended to a distance of about 70 to 80 feet from the end of the complete wall. It was found by sounding with a rod and could be easily recognized. If a section of the wall was left uncompleted, with its top surface below the level of the water, the deposit would occur on this surface, and would have to be removed before more concrete could be placed.

Atlas cement was used in general, but this deposit has occurred in the experience of others in the same class of work, and with other cements. Feret, the French authority on cement, mentions this reaction between cement concrete placed in salt water.

Salt water was used in mixing the cement and gave excellent results. Authorities on cement state that the use or salt water in mixing concrete has no effect on the setting, and this has been my experience, both in work of this character and work in cold weather when salt water was used to prevent freezing.

Two unsuccessful methods of splicing piles were tried before the one finally adopted. At first battens were spiked over the joint between the two sections of pile, but it was found that the least deviation from the vertical pulled these battens off, or they were torn off by being driven through the sand. Another method was by the use of a short piece of 10-inch pipe, supplemented by four angle irons placed vertically on the pile and through-bolted, the one bolt passing through the pile and two opposite irons. Eight $\frac{7}{8}$-inch bolts were used to each splice. When first tried this was thought to be successful, but on the second pile a slight compression of the point of the upper pile brought the bolts into the grain of the wood, splitting the pile into four parts. The final and successful method was the one described in the paper.

The matter of the type of wall used was a question of economy. The type with curtain walls, at first proposed, would have cost between $700,000 and $800,000. The design adopted cost about $350,000.

Paper No. 1022.

GARBAGE DISPOSAL BY REDUCTION METHODS.

D. ROBERT YARNALL.

Read April 7, 1906.

The average American city's waste, not including sewerage, is divided into the following component parts:—Light refuse (including street sweepings), 10 per cent.; ashes, 73 per cent.; garbage, 17 per cent.

By refuse is meant all miscellaneous waste collected from the markets and households, such as paper, boxes, bits of wood, and miscellaneous rubbish, a large percentage of which is combustible.

The 73 per cent. of ashes collected from households, factories, and institutions, in the average American city, contains a very small percentage of unconsumed carbon, a very much smaller percentage than found in foreign practice. The proper use for these ashes is for filling purposes, and under certain conditions they can be used for making concrete.

In this discussion, by garbage is meant animal and vegetable waste matter subject to rapid decay, collected from kitchens, markets, slaughter-houses, etc.

These percentages vary greatly with the geographical location of the community, with the season of the year, and with the particular kind of season; that is, whether rainy or dry, hot or cold. In fact, every change in the natural order of living affects to a greater or less extent the above values and their relation to one another. For instance, the percentage of ashes in our Southern cities is very much lower than in our Northern cities; in our Northern cities it is a great deal higher in winter than in summer, while in the South it is a fairly constant quantity throughout the year.

Then the percentage of garbage will increase materially in the summer because of the large increase in vegetable matter contained therein. In our Southern cities the percentage of grease in the garbage is very low because of the small proportionate consumption of meats.

The kind of season influences particularly the quantity of garbage; it also influences somewhat the quality of the garbage. If for any reason the weather conditions have interfered with the growing of melons, sweet corn, and fruit, the amount of garbage in July, August, and September will decrease surprisingly. On the other hand, if the season

has been favorable the vegetable matter assumes prodigious proportions in these months.

It is interesting to note the difference in the quality of the garbage in our Eastern cities, its physical as well as chemical changes.

The material collected in Baltimore is very inferior, indeed. It contains but a small percentage of grease and a very large percentage of rubbish and objectionable matter. Baltimoreans seem to live largely on fish foods—oysters, crabs, etc. At certain seasons the crab-shells assume surprisingly large proportions; in fact, often at a distance a load of garbage has a decided pink color due to the crab-shells.

Philadelphia garbage is in a very much better mechanical state than that of Baltimore, but the percentage of grease is much lower than in some of the other cities, such as Newark, N. J., New York, and Brooklyn, although much higher than in Baltimore. The reason for this comparatively low percentage of grease in Philadelphia is to be found in the non-enforcement of an ordinance barring private collectors of garbage. A recent Supreme Court decision has sustained such an ordinance. These "hog feeders" go from house to house in the best sections of town and to most hotels and boarding-houses and collect only the best of the material for feeding their swine, and leave for the regular collectors the poorer materials, from which material only a small percentage of grease, as above stated, can be extracted. This practice should be stopped at once, not only because of the poor quality of pork produced by swill-fed hogs, but because by so doing the city will be able to obtain lower bids on the scavenger contracts if the material is to be reduced.

The garbage collected in New York City is the cleanest—containing the least amount of refuse—in any city in the East. The reason for this condition is found in the rigid enforcement of the law governing separation of the three kinds of waste. The fact that the material is richer—that is, contains more grease, ammonia, potash, etc., per ton—in New York City than in any other Eastern city, with the possible exception of Atlantic City, is because of the barring absolutely of all private collectors, and also because of the great number of hotels and apartment-houses from which the waste of foodstuffs per capita is much greater than from private households, or from a less thickly populated community where there is an opportunity to scatter the material, feed domestic animals, etc.

It is interesting to note that the garbage collected in New York City is comparatively dry and can be stacked on scows like hay.

The garbage from Boston is very wet and sloppy (pardon the expression). The scows which transport the material away from the city to the reduction plant have to be provided with high sides to keep the material from running out into the Bay. It is difficult to explain the reason for this condition, but it must be because of some method of doing the work about Boston kitchens which differs from that employed elsewhere; perhaps the dishwater is added to the garbage. It certainly cannot be attributed to the staple food of the Hub, for beans are anything but sloppy. The yield of grease from the Boston garbage is considerably less than the yield from New York, but is greater than the yield from Philadelphia, perhaps because of the greater consumption of fish foods, which are poorer in grease than other meat foods.

The method of collection and disposal of a city's waste is influenced by the size of the community and by local conditions. In considering this problem due regard must be given, first, to the sanitary, and, second, to the financial features. It must be determined whether the three grades of city waste—namely, refuse, ashes, and garbage—shall be collected together in the same wagon and used for filling in land, or else be destroyed at an incinerating plant, or whether the material shall be separated and each part collected in separate wagons specially designed for each grade of waste, and the materials thus collected disposed of by approved methods.

It seems manifestly wrong to pollute clean ashes with putrescible garbage, as this from a sanitary point of view only renders the whole mass unfit for filling purposes. It is necessary, in order that no offence be given to the householder, that the garbage be collected frequently, whereas it is certainly unnecessary to incur the great expense of frequent collection of ashes and rubbish which are not objectionable in the sense that garbage is objectionable.

It is the foreign practice to collect all waste matter together by the same wagons, haul it to a destruction plant where the whole mass is discharged into a furnace and the combustible part consumed. In some cases there is sufficient heat generated from the burning refuse, plus some coal, to operate small lighting plants, with doubtful economy, however, judging from the reports of the Shoreditch disposal works, the most efficient plant of the kind in England.

It is possible for this to be done abroad in certain cases because of the fact, as above noted, that the percentage of unconsumed carbon in their ashes is very high. In England, particularly, open-grate fires are

used almost universally, and the ashes resulting therefrom are very rich in coal. It has also been determined that their refuse contains a larger percentage of combustible matter than is to be found in American refuse. Moreover, the percentage of moisture in their garbage is considerably less than that found in this country, owing to the smaller amount of vegetable matter used for food—that is, green corn, melons, fruit, etc.—in which the percentage of moisture is very high, often as much as 85 per cent. There is therefore less water to be evaporated from their garbage, and a considerably greater calorific value to the remaining waste. It is thus apparent why the English destructor plants have been able to operate successfully where similar plants erected in this country for the same purpose have failed.

American practice, in our Eastern cities at least, is to separate the three parts of our municipal waste, collect the garbage frequently in wagons having water-tight steel bodies, and dispose of it either at a reduction plant or at an incinerating plant. The rubbish, or light refuse, is collected in wagons specially designed for this bulky material, and is hauled either to the incinerating plant or to dumping-grounds in low places in the city. There it is sorted over by Italian scavengers who recover rags, bottles, and other marketable products. Or in some cases, where the city is not provided with an incinerating plant for burning garbage, as in New York and Boston, there have been built special plants for burning the worthless part of this light refuse, the mass having first been sorted over and the marketable products recovered as in the former case. In most of our American cities there is sufficient low ground available for filling purposes, and at short, inexpensive hauls, to last for many years to come.

Having decided that the householder must separate his waste into three parts, depositing each in its particular receptacle—the garbage in a water-tight garbage-can, the ashes in the ash-barrel, and the paper and miscellaneous rubbish in a box provided for the purpose—and having decided to keep the ashes clean and use them for filling, what disposition shall be made of the garbage?

Concerning the relative merits of incineration and reduction methods for the final disposal of this objectionable material much has been said and written. The problem is a very complex one, indeed. What is a merit in one case is a demerit in another. What is advantageous in one city is utterly out of place in another. But there are certain facts which largely govern a decision in all cases.

Generally speaking, in a city whose population is under the 100,000

mark, the returns from a reduction method of disposal are too small to warrant building a plant, unless the contract price paid by the city for the work is high, and the term of contract long—ten years or more. For such cities cremation is unquestionably the proper method to adopt.

Again, generally speaking, in a city whose population is over 100,000 reduction should be the method adopted if the cost alone is considered.

Referring for a moment to the sanitary advantages of the two systems, it has been demonstrated time and again that a reduction plant can be operated near a thickly populated district without creating any offence whatever. To cite a case in point, take the old plant of the American Product Company on the Schuylkill River, in this city, not over two miles from City Hall, and just across the river from the delightful suburban district of West Philadelphia. This plant has been in almost continuous operation for the past twelve years, and who ever heard of any complaint as to its being unsanitary or a menace to public health? If care is taken in the design of a reduction plant, and intelligence used in its operation, there is absolutely no occasion for complaint.

A crematory can also be conducted in a highly sanitary manner; but against most existing plants in this country, at least, complaints have been entered based on the obnoxious fumes emitted from the furnaces, or from the small particles of unburned garbage and dust discharged from the stacks.

Success of both systems, however, from a sanitary standpoint, rests almost entirely with the health officers of a city. If they are so inclined they can prevent either method from being objectionable. It is to be expected that the contractor will object to any measures imposed by the board of health necessitating his installing expensive vapor scrubbing or disinfecting devices. But such measures, provided they are practicable, can be enforced, and the comfort of the complaining district assured.

It is pleasing to the medical mind to consider incineration as the only sanitary method for the disposal of garbage, because by such a method the doctor is reasonably sure of destroying at once all microbic organisms, together with their common feeding-ground. To support him in his theories about incineration, or rather by reason of his opinions, there are to be found a great number of reports by engineers and others, both foreign and domestic, endorsing this method of disposal. It seems to those who are acquainted with reduction methods of disposal that the opinions of these doctors and engineers have been formed

in ignorance of such methods. Their ignorance is due to the fact that there is practically no literature on the subject of garbage reduction, and no reliable American data regarding the exact cost of reduction, or the value and quantity of products extracted per ton of garbage treated, except in the hands of the contractors bidding for city contracts, and they naturally do not care to disclose their knowledge.

It is a fact, however, that may be stated without fear of contradiction, that the net cost of reducing a ton of garbage is less than the cost of cremating the same quantity. This should be apparent to everyone. To burn a ton of garbage, it is first necessary to evaporate the 80 per cent. of water the garbage contains. It must be remembered that less than one-third of the remaining 20 per cent. of the original ton is combustible. Now, under the very best conditions of draft and arrangement of heating surface and design of furnace in boiler practice we are able to evaporate about ten pounds of water per pound combustible. Hence, to burn a ton of garbage coal must be added to it. To be sure, it takes coal to make steam to reduce a ton of garbage, but to pay for this coal are the products extracted. It may be said that if the garbage were not separated from the other combustible light refuse it would require practically no coal to burn the mass. But, on the other hand, if this same light combustible refuse were separated and taken to the boiler-room of the reduction plant it could be used to help generate steam for the latter process. There should be no uncertainty about these points. Given a specific case, results can be accurately predicted.

When all is considered, as far as sanitation goes, there is very little to choose between cremation and reduction of garbage. It must be remembered that the raw material, by reason of its origin, is subject to rapid decay and hence in the hot season is bound to be obnoxious; and it is from the handling of the raw material itself, from the receptacle to the wagon and from the wagon to the plant, that complaints arise rather than from the plant itself, be it a crematory or a reduction plant.

It is the object of the reduction plant to obtain every pound of garbage that can be collected from the city, because the plant's profit depends upon the amount of material treated, the fixed charges being very high. Whereas, on the other hand, there is practically no profit to be derived from the burning of the garbage. The collector for the crematory will therefore do everything in his power to collect as small a quantity as possible and not be detected by the municipal authorities. The only revenue to be derived from the burning of the garbage he collects is from the sale of the ash, but in most cases fertilizer manu-

facturers do not consider this ash of sufficient value for them to cart it away from the plant, let alone pay a price for it, because of its poor mechanical condition.

It is apparent in the case of the reduction contractor that a premium is placed upon honest and efficient collection; whereas, in the case of the burning method of disposal a premium is placed upon dishonest service on the part of the collector. Again, does it not seem manifestly wrong to burn up a material which, if intelligently treated by an approved process, maintains in a community a thriving manufacturing plant? Moreover, is it not manifestly wrong to utterly destroy this material when a valuable fertilizer base can be extracted from it by which, after properly treating it and distributing it throughout rural communities, there may be returned to the earth a valuable plant food which in due time will bring forth an abundance of fruit,—a point which will be more appreciated, perhaps, as time goes on and our soils become further exhausted.

After a most careful and exhaustive study of the whole waste problem of New York City about ten years ago, Col. George E. Waring, Commissioner of Street Cleaning, ably assisted by a corps of competent engineers, came to the conclusion that the most efficient and inexpensive method for the city of New York to adopt in the collection and final disposal of its waste products was for the city to insist, through proper legislation, that the householder separate the material into three parts, as above explained,—the city to provide three separate and distinct kinds of wagons for the collection of these three kinds of waste,—the ashes to be used for filling in land, the refuse to be sorted and burned, preferably by a small city burning plant or plants placed at convenient locations, and the disposal of garbage to be contracted for by private parties who should reduce the same by some approved method, the city itself to organize its own collecting force and do the work of collection.

It is interesting to note that American engineers and municipal authorities in our Eastern cities have largely adopted Colonel Waring's conclusions. It is also interesting to note that the cost of the disposal of city waste is steadily decreasing as the processes of treatment are improving and competition is growing keener.

Having decided that the garbage will be disposed of by a reduction method, it remains to be determined which is the best reduction method. All of the reduction processes are for the purpose of separating the raw material into four parts,—rubbish, water, grease, and tankage. An

average sample of garbage, taken throughout the year, consists of rubbish 6 per cent., or 120 pounds per ton of garbage; water 71 per cent., or 1420 pounds per ton of garbage; grease 3 per cent., or 60 pounds per ton of garbage; tankage 20 per cent., or 400 pounds per ton of garbage.

The 120 pounds of rubbish is composed of a great variety of solid waste matter, such as bottles, tin-cans, rags, bits of wood, shells, etc., which should have been separated and placed in the light refuse-box by the householder and not mixed with the garbage; but perfect separation is well nigh impossible to obtain. The tin-cans, bottles, and rags are generally separated from this rubbish, as will be explained hereafter, and sold to different parties. The cans are put through a detinning and desoldering process, the tin and solder finding a ready market, and the iron remaining is melted up into sash weights. The bottles that are not broken are cleaned and sold to junk dealers to be refilled with cheap oils, ketchup, and other food products. The broken glass is also separated and is sold at so much a ton. The rags are washed, dried, and sold to manufacturers of paper. The cans, delivered, bring about five dollars per net ton; the bottles about four cents per dozen, the broken glass four dollars per ton, and the rags bring half a cent a pound.

The net return from these marketable products is very small because of the amount of labor required to separate them and prepare them for market. The part that is not salable is generally carted away to the dumps, or at certain seasons is burned under the boilers in the plant.

The 1420 pounds of water in the ton of garbage reduced contains a considerable quantity of glucose and suspended matter and a small percentage of ammonia, but it is of only slight commercial value and is allowed to run away into the sewer. When used at all it is evaporated to the consistency of molasses and added to the tankage just before drying, the combination making what is termed "granular tankage" as distinct from "fluffy tankage."

The 60 pounds of grease to the ton of garbage has the greatest value of any of the products of reduction. This grease is of a comparatively low grade and sells for about three cents a pound the year round, the price of the grease varying with the price of tallow, which, on the basis of garbage grease at three cents a pound, would sell at four cents a pound. It is of a dark brown color and has a slight odor of burnt coffee. This grease is used largely for making soap and candles. The greater part of the American output of garbage grease is shipped to

foreign markets, mostly to Belgium and France. It doubtless returns to this country again in forms which have successfully obliterated their origin and which we would scarcely care to own.

The remaining 400 pounds in the ton of garbage is tankage. Tankage is the term used for the solid fibrous matter left after the grease and water have been separated in the reduction process. It is used, when properly prepared, as a base for fertilizers, as it contains small percentages of nitrogen, ammonia, phosphoric acid, and potash.

All the American systems of reduction are either modifications of the Arnold, or mechanical system, or the solvent system.

The solvent system reduces the garbage by first drying it and then treating the dried material with a solvent, such as naphtha or the lighter petroleum oils. This solvent takes up the grease in the process and the grease is then recovered by evaporating off the solvent. The latter is condensed and used over again in the process.

The most successful American system of garbage reduction, however, is the Arnold, which has been for a number of years in successful operation in Boston, New York, Brooklyn, Newark, Atlantic City, Philadelphia, Reading, and Baltimore. It is the system which Colonel Waring endorsed after his most careful investigation of all the reduction and burning systems. It can be operated in a thoroughly sanitary manner; in fact, the degree of perfection to which this feature may be carried lies almost entirely with the city authorities, as previously stated.

As far as the cost of the system goes there is no process known which gives so fair a return to both the city and the owners of the plant. Its decided success in our large Eastern cities is largely owing to its simplicity, its flexibility, its rapidity of operation, its sanitary features, and the low cost for the reduction.

Fig. 1 is a line-drawing showing the details of this system. At the top, supported by the roof trusses, is the raw material conveyor, of standard design, which receives its material from the scows or teams as they unload at the plant, and conveys it to the top of the digester building. On the under side of this conveyor, and usually centered over four digesters, are slides or gates to which are attached several spouts. By properly operating these gates and spouts the tanks are filled in turn.

These digesters, into which the raw material is discharged, are usually built about 6 feet diameter by 16 feet long in the straight. They have a dished head with a 14-inch hinged charging door and a

conical bottom to which is secured a 12-inch discharging gate-valve. After a tank has been properly filled and the cover sealed, steam at about 80 lbs. pressure is turned into the bottom and the digesting

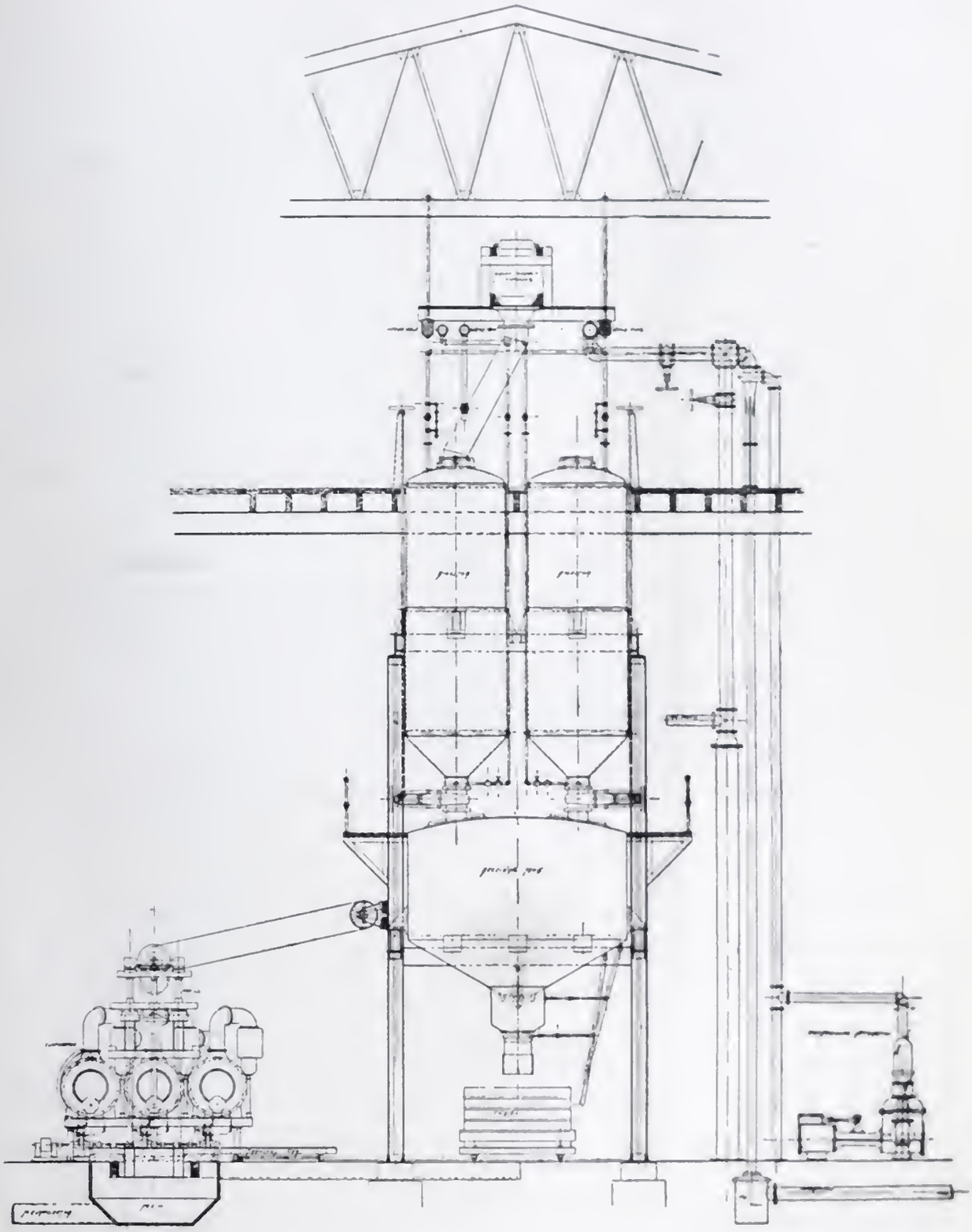


Fig. 1.

begins. This process continues for about eight hours, more or less, depending upon the season of the year. In summer it takes longer

than in winter to cook a tank. In order that the material may be thoroughly digested it is necessary that the tanks be vented. This is done by discharging steam from the top through a ½-inch pipe into a common vapor line as shown on the drawing. The man in charge knows when to turn off a tank by the odor of this vapor. This odor is so very offensive that it cannot be allowed to escape into the air and it is collected into one large main which terminates in a jet condenser, as shown to right of drawing. The tail pipe of this condenser discharges into a convenient sewer. The life of this vapor piping, together with the condenser, is very short because of the decided acidity of the steam. It slowly eats away everything it comes in contact with.

After the tank is thoroughly digested steam is turned off, and when the pressure within is reduced to atmospheric the 12-inch gate-valve at the bottom is quickly opened and the contents of the digester discharged into a sealed hopper-bottomed "receiving tank." This tank is generally made large enough to receive the contents of from two to four digesters, so that the digesters may be discharged and refilled rapidly.

The material in the receiving tank is now ready to be pressed in order to separate the liquids from the solids. The form of press varies in the different plants. Forms in wooden racks and burlap are built up under the spouts until about twelve have been made, when the truck is wheeled over to the press and the moisture and grease are pressed out from the solid, fibrous matter, which latter is known as tankage. When the pressing is finished the truck is wheeled away and the forms stripped, the racks and cloths to be used over again and the tankage to be disposed of as will be explained later.

The hydraulic press has supplanted in large measure the old screw press. The two operate similarly, except that in one case the pressure is applied by means of four screws and in the other by water pressure behind a piston in a (vertical) cylinder. But the most generally satisfactory press is the Edgerton roller press, shown in Fig. 3. It is to be noticed that in this machine the receiving tank is riveted to the sides of the press, which makes it very much better from a sanitary point of view, as all the drainage is within rather than without the press, as in other forms. In the roller press there are two continuous conveyor aprons,—the upper one, called the feed apron, and composed of steel slats 3 inches wide, ½ inch thick and 3 feet long, riveted close together to three heavy parallel drop-forged chains which are driven by sprockets at one end. As this feed apron moves the material in the tank is

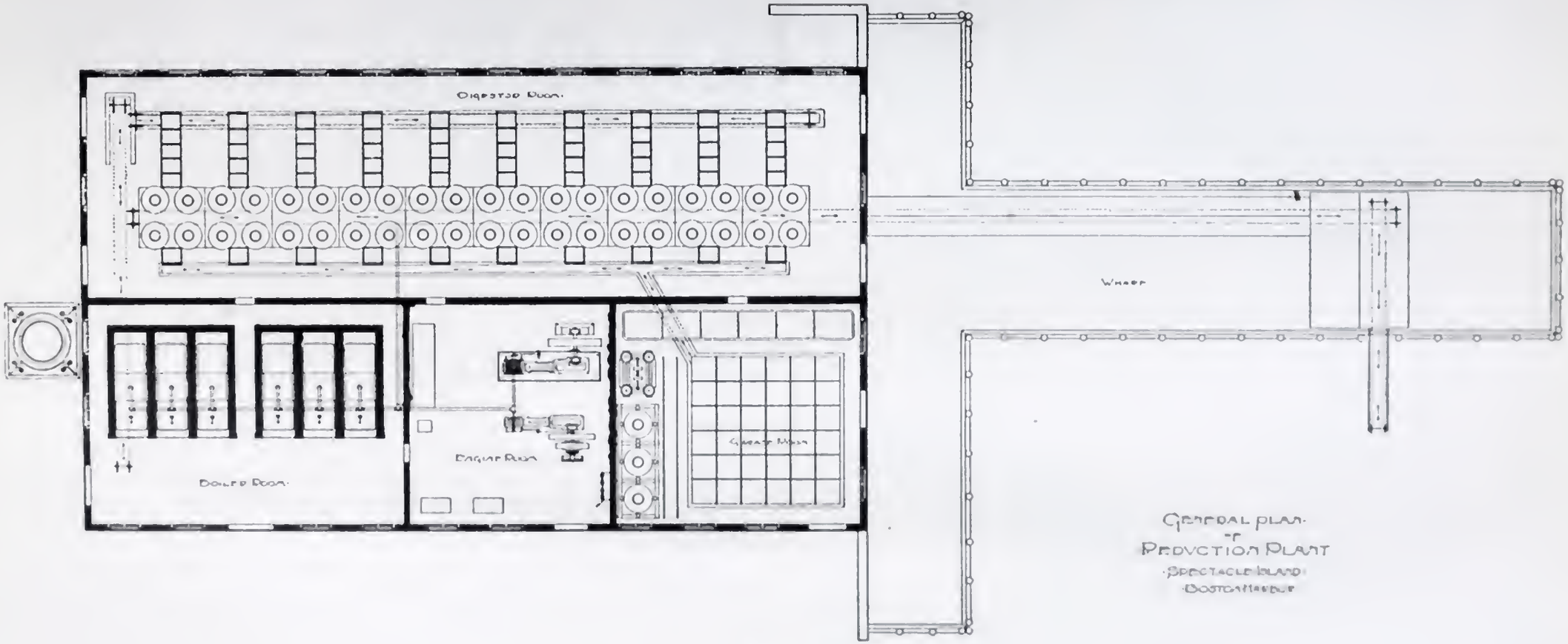

Digester Room
Boiler Room
Engine Room
Wharf
General plan
of
Reduction Plant
Spectacle Island
Boston Harbor

Fig. 2.

slowly worked to the front, where it is discharged on to the lower apron, which is composed of perforated slats 3 inches wide by $\frac{3}{8}$ inch thick by 3 feet long, rivited to three parallel chains as in the feed apron. This perforated apron is continually passing between three pairs of heavy rolls held together by helical springs which give the desired pressure on the material, and at the same time, if required, allow bits of stone or iron to pass through without breaking the machine.

The liquids are pressed out through the perforations in the apron slats, and flow down into a center drain under the press and thence to the catch-basins, where the grease rises to the surface and is pumped up into settling tanks to be prepared for market.

The solid matter, or tankage, is discharged from the end of the press into a conveyor which carries it either into the boiler-room, where it is used for fuel, or into the drying department, where it is dried down to 10 per cent. moisture and bagged and subsequently sold to the manufacturers of fertilizers. The analysis of this tankage varies greatly in different parts of the country and at different seasons of the year. A fair average analysis taken right from the press would be:—

Moisture	38 to 44 per cent.
Grease	5 to 9 per cent.
Nitrogen, equivalent to ammonia	1.2 to 2.2 per cent.
Phosphoric acid, equiv. to bone phos. of lime	4.2 to 7.2 per cent.
Potash	2 to .3 per cent.

It is always a problem to decide what to do with the tankage at a given plant. At times when grease is selling very low and coal is high in price and there is small demand for low grade ammoniates, it pays to burn it under the boilers. Tankage, however, is decidedly inferior fuel because of its low calorific value, and also because of very troublesome clinkers that are continually forming. Tankage ash is worth about $1.50 per ton delivered for the fertilizing ingredients it contains.

If there is a demand for tankage in the fertilizer market it pays to dry the material down to 10 per cent. moisture, or commercially dry, when its analysis should show:—

Moisture	10. per cent.
Ammonia	2.8 "
Phosphates	8.5 "
Potash	.31 "

This dry tankage should sell at from $6 to $8 per net ton.

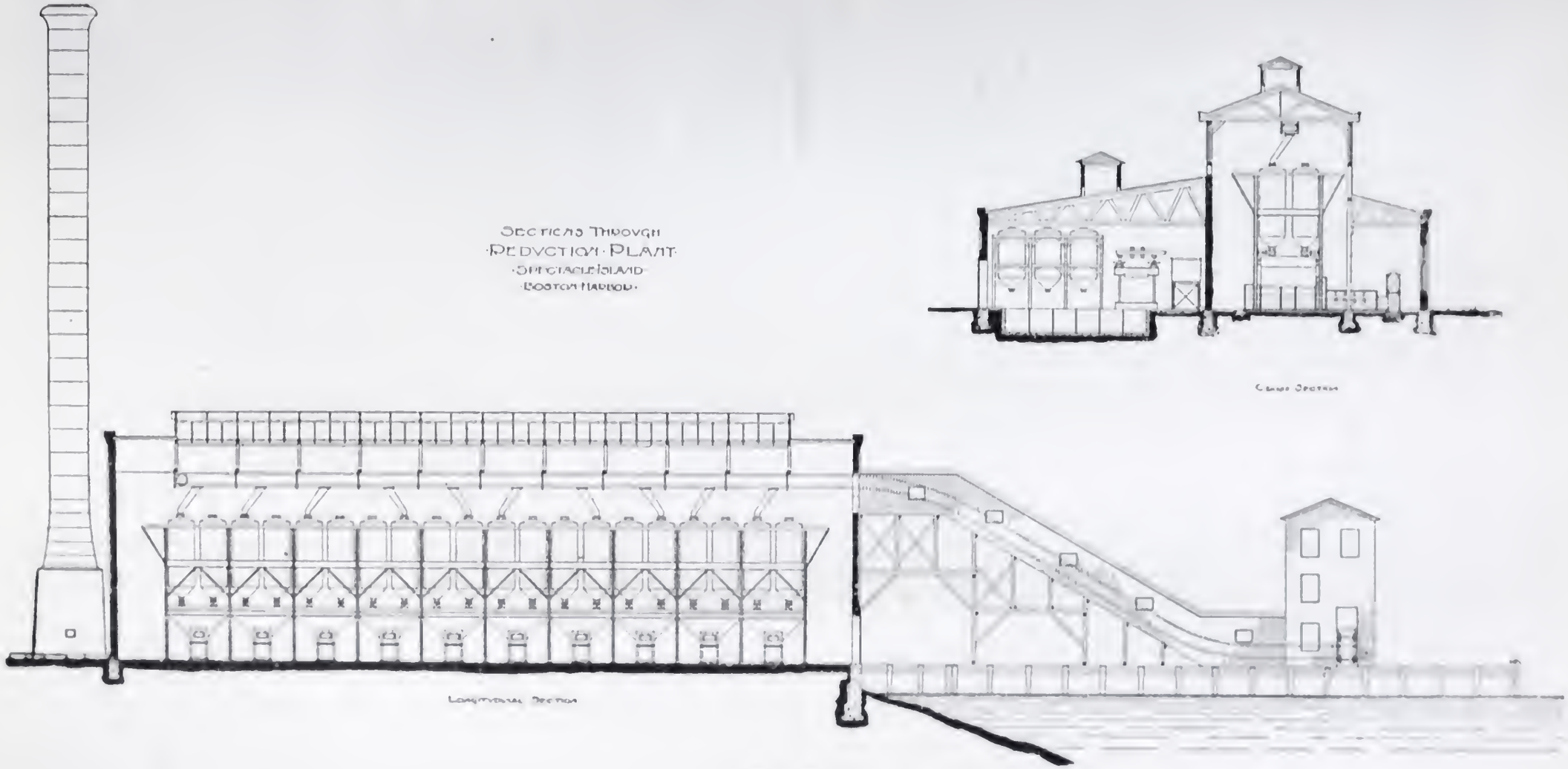

Sections Through
Reduction Plant
Spectacle Island
Boston Harbor
Longitudinal Section

Fig. 3.

If the grease market is strong and the price of solvents within reason, under certain conditions it is advisable to extract the 6 per cent. or 9 per cent. grease which the tankage contains by percolating it with solvents, such as the lighter petroleum oils, benzine or naptha, or by the use of carbon bisulphid, or carbon tetrachlorid. The latter solvent is noninflammable, but unless diluted with a cheaper solvent its cost is prohibitive.

The best method of treatment is to first dry the tankage and then percolate it, using the same liquor over and over again, until it is sufficiently concentrated, when the system is allowed to drain into an evaporator which drives off the lighter solvent to the condenser, leaving the heavier garbage grease which is prepared for market. The solvent held by the tankage is recovered by the application of heat to the percolating tank. It is interesting to note in this connection that the tankage from which the grease has been extracted is now of greater value as a fertilizing material. The grease thus extracted, however, is not as valuable as that extracted by mechanical means.

The catch-basin liquor, after the grease has been taken off, has very small commercial value because it is so very dilute. It contains from .15 to .4 per cent. ammonia, and in some cases we have evaporated it down and added the concentrated liquor to the tankage during the drying process. This makes a granular tankage which is in greater demand than the fluffy kind, but the price obtained is only a little better,—in fact, is hardly enough to pay the cost of evaporation and maintain the evaporators. The cost for evaporator repairs is very high because of the acidity of the liquor, which attacks both shell and tubes, whether of iron, steel, copper, or brass.

The New York garbage plant on Barren Island is the largest reduction plant in the world. In the summer months it disposes of 3000 tons of raw material every day. One can scarcely realize the enormous bulk this tonnage represents without spending twenty-four hours on the island in August. The New York Board of Health is very vigilant in preventing obnoxious vapors from arising from this plant because of its close proximity to Rockaway Beach and Coney Island. It requires the fumes to be washed thoroughly in great scrubbers before discharging them into the air.

Figs. 2 and 3 show in detail the construction of the Boston plant on Spectacle Island, Boston Harbor. It is to be noted that the roller presses are used in this plant. The layout is very similar to the Baltimore plant. The three small digesters in the grease room and

one screw press are used for storing and pressing "silt." This is the fine sediment and fibrous matter that washes down from the roller presses into the catch-basins and has to be pressed in a filter press in order to recover the grease that it has carried down with it.

About two years ago a disastrous explosion occurred in the Boston plant. One is never sure just what ingredients form the conglomeration with which the digesters are filled, and in this case an excessive pressure was formed in one of the tanks from an unknown cause and the explosion resulted, completely wrecking the building.

The records of the quantity of garbage treated at various reduction plants are interesting when examined together. The fluctuation in volume and character from month to month is fairly parallel—the yield highest in August and September—except in the case of Boston where the greatest yield is in winter, due probably to the greater proportionate summer exodus of the leisure class. The antithesis of this is observed in the plotted curve of quantity at Atlantic City, which has a great peak in the middle of August, the height of the vacation season, as would be expected from such a resort.

The character of the product varies also; but, unfortunately for the reduction plant, the value of the material expressed in terms of grease is much lower per ton when the quantity handled is the greatest.

These records show that a reduction plant should be made sufficiently large to handle the peak of the load in July, August, and September, although during the remainder of the year, in most cases, two-thirds of the plant must remain inoperative. Moreover, when this great bulk of garbage is being treated the yield of grease—the principal source of revenue—is least, which is certainly an unsatisfactory condition from a manufacturer's standpoint. This explains the fact that the garbage reduction contractor cannot undertake such a contract without being paid a bonus by the city.

DISCUSSION.

D. R. Yarnall (in answer to questions).—In some cities the collection of the garbage is done by the contractors for the reduction; in others the work of collection is done by city employees, which is the practice in New York and Boston. In Philadelphia the collection and reduction are included in one contract, and, because of the great extent of the city, it is a large one with some unsatisfactory attendant conditions. Probably the best solution of the problem will be to make the collection in cans of some uniform design with tight covers, transporting the cans and emptying them at the reduction plant, always leaving an empty can with the householder when the filled one is taken away. Of course the expense of collection will be much greater for such a system.

The cost of reduction depends in a large measure upon the length of term of the contract, because the plant requires a very considerable outlay of capital to build and the first contract must pay for it, there being no assurance of a second. Most of the contracts for reduction of garbage are for a term of years, either five or ten. In Boston they have a ten-year contract; in New York five, and in Newark, N. J., five. In Philadelphia the term is only one year.

It is not generally known what becomes of the extracted grease. Much of it doubtless goes into soap. Chemically there is nothing the matter with the grease; but the odor and appearance are unpleasant. It yields considerable glycerol, and the residue is fatty acid which is proportionately rich but not as rich as tallow. In Belgium and France the glycerol is extracted and possibly used in the manufacture of high explosives.

Henry Leffmann.—What becomes of the grease is probably more a matter of sentiment than of sanitary importance. It could not enter into any food article unless thoroughly purified. It would have to be deprived of its odor and color and it would probably be so completely freed from injurious ingredients that it would not be unfit for use. The association of ideas is sometimes very unpleasant but is not necessarily of importance in the sanitary question. The probability is that this grease goes more into the manufacture of fancy soaps and toilet articles than into food products. The glycerol taken from it, if used in making high explosives, would have to be of high quality, and the manufacturer would therefore subject it to a thorough examination. From my own experience I know that this grease will yield quickly a nearly colorless soap; the amount of coloring matter is very small. These two articles, therefore—soap and glycerol—will not, as they come from the manufacturer, be objectionable, for the processes of manufacture would destroy any matters that could be considered disease-producers.

It is a very important part of garbage reduction to clarify the grease, because it is in demand and is valuable; but other questions arise and claim at least equal attention. We have only to keep our eyes and noses open in Philadelphia to be impressed with the defects of the system employed here. It will probably not be satisfactory until different methods are adopted, beginning in the household and continuing to the factory. The system of building which is followed in Philadelphia in recent years tends to make the collection of garbage more difficult than it might otherwise be. Rows of houses built in blocks, with narrow alleys between them, result in a very unsatisfactory state of affairs. Garbage cans and boxes are kept in these alleys until they become putrid and offensive; sometimes they are kicked over, and in some instances the garbage is rarely collected. The garbage should be kept in a can which will be taken away by wagon. This branch of the question of the disposal of refuse will never be settled until official interference is in vogue. It is unfortunate that the average citizen cannot be trusted to attend to these things in the proper way.

MEMOIRS.

HERMAN HAUPT.

Gen. Herman Haupt entered the Engineers' Club of Philadelphia as one of its first two honorary members, on April 6, 1878, within six months of its organization, and during the presidency of his son, Prof. Lewis M. Haupt.

General Haupt's record may be briefly summarized as follows, from a manuscript prepared by himself for his son about six years ago:

1817 March 26, born in Philadelphia.
1828 Haupt's father died, leaving a widow with several children and without means.
1831 Entered West Point Military Academy.
1835 June, graduated from West Point, and commissioned Brevet Second Lieutenant in the Third Regiment of Infantry.
1835 August, draftsman for Henry R. Campbell.
1835 Autumn, under Mr. Campbell on the survey for the Norristown and Valle Railroad, from Norristown to Allentown, via Perkiomen Creek.
1836 Elected member of the Franklin Institute.
1836 Spring, engaged in location of the Chester Valley Railroad.
1836 June, to 1839, on location and construction of the Gettysburg Railroad across South Mountain, to connect with the Baltimore and Ohio Railroad.
1838 Married Anna Cecilia Keller, of Gettysburg, Pa.
1840 Principal assistant to Samuel W. Mifflin on the York and Wrightsville Railroad.
1841 Farming on the Eastern Shore of Maryland.
1842 to 1847, teaching school at Gettysburg, Pa., and professor of mathematics at Pennsylvania College.
1847 Engaged on the relocation of the Juniata Division, Pennsylvania Railroad.
1847 Principal assistant engineer Pennsylvania Railroad.
1848 Assistant to chief engineer Pennsylvania Railroad, Harrisburg, Pa.
1849 Studied the system of organization of railroads in New York and New England, and submitted a plan, which was accepted, for reorganizing the business of the Pennsylvania Railroad.

1849 September 1, appointed superintendent of transportation, Pennsylvania Railroad.

1851 "General Theory of Bridge Construction" published by D. Appleton & Co., New York.

1851 January 8, appointed General Superintendent Pennsylvania Railroad.

1852 Chief Engineer Southern Railway of Mississippi.

1853 April 30, succeeded J. Edgar Thomson as Chief Engineer Pennsylvania Railroad.

1855 November 23, elected by Philadelphia City Councils a director of Pennsylvania Railroad.

1856 Resigned as chief engineer and director Pennsylvania Railroad, and entered into a contract for building the Hoosac Tunnel; became chief engineer and director of the Troy and Greenfield Railroad.

1858 Designed the first automatic-feed, reciprocating, steam-power rock drill.

1862 Appointed aide to General McDowell with the rank of Colonel and Chief of the Bureau of Military Railroads.

1862 September 5, promoted to Brigadier-Generalship for meritorious service in operations during Pope's campaign.

1863 Discovered the design of General Lee in his movements antecedent to the Battle of Gettysburg.

1864 "Military Bridges," a work of 310 pages, with 69 plates, published by D. Van Nostrand, New York.

1871 Elected a member of the American Philosophical Society.

1874 General manager Richmond and Danville Railroad system, and director of company.

1875 Organized the Southern Railway and Steamship Association.

1876 Chief Engineer Pennsylvania Transportation Company and Seaboard Pipe Line.

1879 Made an examination and report on the use of compressed air for city and suburban railway service.

1880 Consulting engineer Hydrogen Company.

1881 to 1884, General manager Northern Pacific Railroad; line completed and opened in the fall of 1883.

1884 President of the Dakota and Great Southern Railroad.

1891 Made report on artificial harbors for the coast of Texas.

1892 to 1898, President and consulting engineer of the General Compressed Air Company, and of the American Air Power Co.

1895 Made a report on long-distance transmission of compressed air at high pressure for power.
1898 President of the National Nutrient Company.

His death, due to heart failure, occurred December 14, 1905, during his return, by railroad, from New York (whither he had gone in connection with business of the Nutrient Company) to his home in Washington. He was accompanied by his son, Prof. Lewis M. Haupt.

It was during his work on the York and Wrightsville Railroad, under Samuel W. Mifflin, in 1840, that he was called upon to construct bridges, and he set about ascertaining the stresses in their several members. In search of information upon this subject he "corresponded with nearly all the principal engineers in the United States to learn how to calculate the strength of a truss bridge." He writes: "To my great surprise, I found that no attempts were made to make calculations, and the strain sheets, showing the distribution and magnitude of strains, were entirely unknown. Even counter-braces, so essential to rigidity of structure, were not generally employed in the railroad and other bridges of the day." He then entered into a study of the subject, which resulted, in 1851, in the publication of his "Theory of Bridge Construction."

In his "Chronological Record," above quoted, General Haupt remarks that his "Theory of Bridge Construction" "elicited high commendation from Robert Stephenson and his associates in England."

In his "Reminiscences," published in 1891, his editor, Mr. Frank A. Flower, tells of a visit which Haupt received from his chief in 1848, while assistant to the chief engineer of the Pennsylvania Railroad, Mr. J. Edgar Thomson, who, noticing a model of a bridge truss resting on two chairs and loaded with weights, remarked, with a smile: "Some fellow has been trying to make a bridge and don't know anything about it. He has got his brace in the wrong way;" whereupon the assistant was forced to explain to his chief the nature and office of a counterbrace.

As superintendent of the Pennsylvania Railroad Mr. Haupt advocated "low rates with moderate dividends" as a means of securing a traffic of a million tons, and of making the road an instrument of incalculable good to the citizens of the State. He urged the purchase, by the Pennsylvania Railroad, of the Powelton estate, in West Philadelphia, through which Powelton avenue now passes; but the scheme was thought Utopian at the time. It was in his administration as chief engineer that the entire road was opened to Pittsburgh.

As aide to General McDowell, in 1862, Haupt was charged with the construction and operation of the military railroads of the United States, and authorized to form a special corps, and to take military possession of any road which he considered necessary for government service. His corps accompanied Sherman in his historic march through Georgia. The editor of his "Reminiscences" writes: "If Meade had acted, or if any one had thought to place Haupt in command on Sunday, July 5, 1863, Lee would doubtless have been captured and the Rebellion ended."

As chief engineer of the Seaboard Pipe Line he received a unanimous vote of thanks from the Councils of Baltimore for his activity and enterprise in securing a continuous right of way for a pipe line from the oil regions to the seaboard, prior to the existence of any general laws governing such matters, and for the subsequent building of a line which reduced the cost of transportation of oil from forty cents a barrel to four cents a barrel.

General Haupt's "Reminiscences" are confined chiefly to his military experiences and are made up largely of the correspondence which passed through his hands during the war, with excellent and admirable illustrations of some of the works under his charge, and of the expedients which he adopted to accomplish the desired ends. Of this volume Mr. Henry Carey Baird writes: "It reads like 'The Arabian Nights,' a story of the impossible! It also presents a life-picture of a man not only of executive ability supreme, but of ingenuity *to fit.* It is one of the most instructive books in the English language, and I have read it faithfully from the title to the last page of the appendix."

Mrs. Haupt died in 1893. They had eleven children, of whom seven survive him. Among the latter is his son, Prof. Lewis M. Haupt. An elder son, Jacob Benjamin, a mechanical engineer associated with William Sellers & Co., died in 1905. He had given much attention to the development of the steam fire-engine.

General Haupt's long, eventful, active, and distinguished career, of which we have sought to present an outline, richly entitles him to a standing among the giants of his profession. Seldom if ever do men continue, as he did, in active service as engineer for more than three score years and ten. Notable not only for his brilliant activity during nearly the whole of the Civil War but for eminent services in more peaceful lines, including especially the development of the railroad and of the oil pipe line, conspicuous also as a pioneer among authors in the science and art of bridge building, the honor which this Club sought to bestow upon him has reverted in large measure to the Club itself.

His modest and retiring disposition, and his residence during many years in other cities, forbade any large degree of intimate personal acquaintance with the members of our Club. But his personal qualities are well summed up in the following tribute to his memory from the pen of his son, our first President:

"As a man, General Haupt was unostentatious, domestic, loving, tender-hearted, upright in all his dealings with his fellow-men, having a keen sense of justice, righteousness, and obligation to duty regardless of appearances, faithful to every trust, and in every act inspired by his strong faith in the brotherhood of man and the fatherhood of God. His life has been an honor to his profession and a blessing to humanity. He was an instance of a man whom the Lord delighted to honor."

John C. Trautwine, Jr.
Benjamin Smith Lyman.
William Easby, Jr.

MAX LIVINGSTON.

Max Livingston became a member of the Engineers' Club of Philadelphia on May 2, 1885. He was a member of its Board of Directors in 1896–97; but he steadfastly declined nomination to higher offices in the gift of the Club. He died in New York on February 16, 1906.

He was born in Hagen, Westphalia, Prussia, January 16, 1845, and attended the Gymnasium in Bielefeld, Westphalia.

At the age of sixteen years he came to America, and lived for a while in Amesbury Mills, Massachusetts, where he made the acquaintance and became the friend of the poet Whittier.

Two years later he took up his home in New York, and for two years more devoted himself to the study of social and economic questions.

In 1865 he went to Pittsburg, Pa., and that city was his home for nearly twenty years, during which time he was an active member of the Engineers' Society of Western Pennsylvania and a contributor to its "Proceedings." He appears to have been one of its charter members.

In Pittsburg he attended the Western University of Pennsylvania, and later he joined his brother, Mr. Julius I. Livingston, under the firm name of Livingston Bros., in the business of producing and refining petroleum.

Mr. Livingston's intimate scientific and technical knowledge of the properties of petroleum soon gained for the firm a wide reputation for its product of high-grade, non-explosive burning oil, in the manufacture of which they were pioneers.

In October, 1882, he read, before the Engineers' Society of Western Pennsylvania, a paper ably discussing the history, geology, manufacture, and uses of petroleum, its service in the arts, and its contribution to the comfort and enlightenment of mankind.

Upon the absorption of the firm by the Standard Oil Company, in 1874, Mr. Livingston was made superintendent of the works at Pittsburg, but in 1884 he was transferred to Philadelphia as General Superintendent of the Manufacturing Department of the Atlantic Refining Co. at Point Breeze.

In 1900–01 he made a tour of the world in the interests of the Standard Oil Company, visiting the principal oil-producing and refining plants in Europe, Japan, China, and India.

In February, 1903, he retired from the active service of the Company.

In 1868 Mr. Livingston married Laura, daughter of Baron von Weydemeyer, who was an eminent artillery and engineer officer in the Prussian service, but who left that service in 1848 and joined the revolutionary party of that celebrated period. When this movement failed, Baron von Weydemeyer came to the United States and devoted his time to literary work and to engineering. At the breaking out of the Rebellion, in 1861, he volunteered, and was soon made Chief of Staff of General John C. Fremont in the Union Army.

Deep as was Mr. Livingston's interest in the technical work to which most of his life was dedicated, he was, if possible, even more profoundly interested in matters more deeply and broadly affecting the welfare of the race.

From his early years he was an enthusiastic student of social problems, and he was deeply impressed with the force of the teachings of the late Carl Marx; so much so, indeed, that while he took a lively interest in matters looking to the improvement of existing political conditions, he could not escape the conviction that all such activities were merely scraping the surface of things, and that no lasting or thorough improvement was possible until the social pyramid should have been placed upon its base and not upon its apex.

In the paper, already mentioned as having been read before the Engineers' Society of Western Pennsylvania in 1882, he mentions, as demonstrated by the history of the petroleum industry, "that doctrine of political economy which avers that the work requisite to supply the wants of humanity will eventually be performed by concentration of capital and combination on a large scale of machinery and labor through the agency of powerful corporations, either for their own benefit or that of society," and refers to the Standard Oil Company as illustrating the fact that "in the ratio as such concentration of capital takes place, implying as it does the expropriation of the many smaller capitalists by a few greater ones, the application of technological science and the systematic development of the resources of the earth progress"; and in an address, delivered before the senior class of the Wharton School of Finance and Commerce of the University of Pennsylvania in May, 1904, he maintained that "integration, or the uniting of all stages of production and distribution under a single ownership, or, in other words, the underlying principle of the great latter-day combinations, is destined to continue, and capable of being expanded indefinitely."

He was an enthusiastic and skilful chess-player and a member of the

Franklin Chess Club. He entertained Lasker, Zuckertort, and many other eminent players.

He was a well-beloved husband, the happy father of a devoted family, the center of a host of genial friends, and was possessed of ample means for all the comforts and many of the luxuries of life. He enjoyed a standing at the head of his profession, and the confidence of the corporation which he had served for more than a quarter of a century; but he was the victim of cruel suffering, due to tic-douloureux, on account of which he was repeatedly subjected to serious and painful surgical operations.

Mr. Livingston's modesty prevented him from becoming as widely known, in the Club he served, as his admirable qualities of mind and of heart would have warranted. But what most of his fellow-members lost, in this respect, was more than made up to those who had the good fortune to be of the social circle of which his family was the center.

Here, if ever, there was open house, and within the open house were open hearts and hands and generous welcome and good cheer. To those who enjoyed the fellowship of this circle, the name of Max Livingston will ever remain a synonym for all that is lovely and of good report.

On 16th February last, while visiting his brother, Julius, in New York, he complained of slight indisposition and lay down for a few minutes' nap, from which, it is believed, he never awakened. When his daughter went to call him, she was dismayed to find him dead. His death appears to have been caused by some valvular derangement of the heart or else by an attack of his old enemy upon his brain.

He leaves a widow, two daughters, and two sons. His elder son, Herman, is a member of the Club, having been admitted to active membership April 16, 1898.

John C. Trautwine, Jr.
Louis Schutte.
Henry J. Hartley.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, April 7, 1906.—President McBride in the chair. Seventy-one members and visitors present.

The Tellers reported the election of D. M. Rice to active membership; Edward B. Myers, E. I. Snyder and Howard M. Yeager to junior membership, and A. H. Whiteside to associate membership.

Mr. D. Robert Yarnall read a paper on "Garbage Disposal by Reduction Methods."

Regular Meeting, April 21, 1906.—President McBride in the chair. Sixty-four members and visitors present.

The Secretary read a Memorial of General Herman Haupt, deceased.

Mr. C. O. Mailloux read a paper on "Mechanical Integration with a Special Reference to the Integraph."

Business Meeting, May 5, 1906.—President McBride in the chair. Sixty-nine members and visitors present.

The Tellers reported the election of E. T. Hannam to active membership and William D. Polk to junior membership.

Mr. John C. Trautwine, Jr., read a letter from Mr. Otto von Geldern, of San Francisco, stating that nearly all the engineers of that city had lost their entire equipment of instruments, books, etc. It was resolved that all those who wished to furnish financial assistance should hand the same to the Secretary.

Mr. Frank B. Gilbreth read a paper on "Corrugated Concrete Piles."

Business Meeting, May 19, 1906.—President McBride in the chair. Sixty-eight members and visitors present.

Mr. J. W. Ledoux read a paper on "The Water Works of Charleston, S. C."

Mr. Francis Head read a paper on "A Comparison of the Cost of Pumping Machinery Driven by Steam and Oil Engines."

The Secretary read a Memorial of Mr. Max Livingston, deceased.

It was moved and carried that the Club furnish to the Technical Society of the Pacific Coast a full set of the Proceedings of The Engineers' Club of Philadelphia and to individual members of that Society any desired copies at 15 per cent. of the regular price; also that members of The Engineers' Club be invited to hand voluntary contributions to the Secretary for transmission to the above Society.

Business Meeting, June 2, 1906.—President McBride in the chair. Fifty-four members and visitors present.

The Tellers reported the election of J. McD. Greene, R. C. Heath, Robley A. Turner and John C. Trautwine, 3d, to active membership; Richard P. Brown to junior membership, and Jno. W. Allison to associate membership.

The Nominating Committee, nominated by the Board of Directors, was announced as follows: S. G. Comfort, Chairman; E. F. Miller, W. B. Riegner, Latio A. Foster, and C. H. Ott.

Mr. S. W. Kapp read a paper on "The Foreman: His Training, Work, and Relation to Maintenance of Way Organization."

The President announced the result to date of the subscriptions to the fund for the San Francisco sufferers

Mr. Perrot, chairman of the committee to consult with the Chief of the Bureau of Building Inspection, reported that the committee was not prepared to make a final report.

A motion was made that the Board of Directors be instructed to prepare plans for extensive alterations in the Club House. On account of a provision of the By-Laws the motion was ruled out of order, and notice was then given that the motion would be brought up at the September meeting.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, April 21, 1906.—Present: President McBride, Vice-President Devereux, Directors Dallett, Easby and Loomis, and the Secretary.

The report of the Treasurer for the month of March was read and accepted, as follows:

Balance, February 28, 1906,	$5241.02
March Receipts,	545.00
	$5786.02
March Disbursements,	620.75
Balance March 31, 1906,	$5165.27

The Library Committee reported the purchase of the New Internationa Encyclopedia on the basis of $65 cash and $55 worth of advertising.

The House Committee reported the renewal of the lease of the Club Hous until April, 1907.

The letter of resignation of Mr. John Nazel was referred to the Treasurer f action.

Upon consideration of the letter from Mr. Wm. C. L. Eglin, offering on beh of Mr. Spalding and himself to present to the Club a framed photograph of M Spencer, it was decided as the sense of the meeting that the offer should declined, with thanks.

Regular Meeting, May 19, 1906.—Present:—President McBride, Vi President Devereux, Directors Dallett, Dodge, Head, Loomis and Quimby, a the Secretary.

The report of the Treasurer for the month of April was read and accepted, follows:

Balance March 31, 1906	$5165 27
April Receipts	276 56
	$5441 83
April Disbursements	483 83
Balance, April 30, 1906	$4958 00

It was moved as the sense of the Board that the Club donate a complete set of the Proceedings of the Club to the Technical Society of the Pacific Coast, but that any cash contribution be made by individual members of the Club.

The Library Committtee reported the purchase of a set of the Americana Encyclopedia for $48 in cash, and the remainder to be paid for by advertising in the Proceedings.

Special Meeting, June 2, 1906.—Present: President McBride, Vice-President Devereux, Directors Dallett, Dodge, Head, Loomis and Quimby, and the Secretary.

It was moved and carried that the Chair should announce to the Club, at the meeting later in the evening, the result of the subscriptions to aid the San Francisco sufferers and appoint a committee to carry out the provisions of the resolution adopted at the previous meeting.

It was moved that the resignation of Mr. Joseph B. King, First Vice-President, be laid on the table.

It was moved and carried that the Publication Committee order fifty reprints of the Memoir of Mr. Max Livingston and send them to the family of Mr. Livingston without cost.

The Nominating Committee was nominated as follows: S. G. Comfort, Chairman; E. F. Miller, W. B. Riegner, Horatio A. Foster and C. H. Ott.

ADDITIONS TO THE GENERAL LIBRARY.

FROM FAIRMOUNT PARK ART ASSOCIATION.

Thirty-fourth Annual Report of the Board of Trustees.

FROM UNION LEAGUE.

Union League, 1905.

An Address by Rear Admiral Joseph Adams Smith, U. S. N., on "The Kearsage and Alabama."

FROM BELL TELEPHONE COMPANY.

Memorial of Theodore Spencer.

FROM A. GIBB MAITLAND.

Annual Progress Report of the Geological Survey of Western Australia, for the year 1905.

FROM COMMITTEE ON INTEROCEANIC CANALS.

Testimony and Supplemental Statement of John F. Wallace.

FROM METROPOLITAN WATER AND SEWERAGE BOARD.

Fifth Annual Report of Metropolitan Water and Sewerage Board, Boston.

FROM UNITED COKE AND GAS COMPANY.

United-Otto System of By-product Coke Ovens.

FROM MAX E. SCHMIDT.

Argument on the Brooklyn Bridge Problem.

FROM ADVISORY BOARD OF CONSULTING ENGINEERS.

Report to the Governor of the Advisory Board, etc.

FROM PHILADELPHIA YACHT CLUB.

Philadelphia Yacht Club, 1905.

FROM WESTMORELAND CLUB.

Westmoreland Club, 1905.

FROM ATHLETIC CLUB.

Athletic Club of Philadelphia.

FROM THE ENGINEERS' CLUB OF NEW YORK.

Constitution, Rules, Officers and Members of the Engineers' Club of New York, 1905.

FROM KNICKERBOCKER CLUB.

Constitution and Rules, Officers and Members of the Knickerbocker Club, 1906.

FROM THE CIVIC CLUB.

Civic Club of Philadelphia, 1905.

FROM LIBRARY OF CONGRESS.

Select List of Recent Purchases, Science.

Classification, Science.

FROM THE CITY ENGINEER.

Report of the City Engineer, Fall River, Mass., 1905.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XXIII. OCTOBER, 1906. No. 4

PAPER NO. 1023.

NEW WATER SUPPLY FOR CHARLESTON, S. C.

J. W. LEDOUX.

Read May 19, 1906.

IN the early part of the seventeenth century Charleston, S. C., was located about twenty miles southwest of the present site on the banks of the Ashley River, and there are now evidences of that settlement in the shape of old ruins, one being known as the old Spanish Fort, made of concrete composed of shells and mortar. There are many other interesting landmarks of Charleston's previous history, one being the Goose Creek Church which appears to be in about the same condition as it was one hundred years ago; and there is a Society, known as the Goose Creek and St. James Parish, which has perpetuated its memory by holding services in this church once a year ever since. Some of the churchyard graves date back to the seventeenth century. There are several other places of equal antiquity and historical interest.

About 1678 the settlement on the Ashley River was abandoned on account of the encroachments of the Indians, and the settlers moved to the peninsula between the Ashley and Cooper Rivers, the present site of Charleston.

In those days, the inhabitants being few, water was taken from shallow wells, but as the population increased it was found that the wells became hard, impure, and injurious to health. The wealthier

citizens began to gather the rain water that fell on the roofs into water tight cisterns, usually built in the ground to preserve and cool the water for domestic purposes. As the wells became fouler, such cisterns gradually came into use among the middle classes, and finally even among the poorest, until a cistern for rain water became a necessary adjunct to a dwelling of any kind in Charleston. Early in the nineteenth century thoughtful minds began seriously to consider from what other source the city could obtain a general water supply of satisfactory quality. Various plans were proposed; one of them was to gather water from springs and convey it through wooden pipes, or even in carts to the city. Such plans seemed insufficient, visionary or extravagant; at least nothing was done by the city authorities. About 1820 one of the citizens sank a well to a depth of fifty-seven feet, which was far deeper than any in use up to that time. This well is believed to be in existence and in actual use up to this time, being located on the north side of Queen Street between King and Archdale. After that a number of wells were sunk to the sixty-foot stratum. In 1823 the City Council determined to sink what they called an artesian well, or one of several hundred feet in depth. After many difficulties and repeated trials to sink artesian wells in various locations, and as many failures, and intermittent work for twenty-six years, they obtained a well about 1260 feet deep, this one alone having cost over $30,000.00. The well was so small that a very insignificant quantity of water was obtained, but the head was sufficient to raise the water about twenty-five feet above the surface of the ground. Nothing further of material value or importance was accomplished until about 1880 when a well nearly two thousand feet deep was sunk. Since that time two other wells were sunk, and until 1904 these artesian wells, one of which was the 1260 foot well, constituted the water supply of Charleston.

From 1876 the water works was owned by private corporations. The service was seldom satisfactory, the vicissitudes of the Water Co. being many and even the interest on the bonded indebtedness was not always paid. The artesian wells yielded a maximum of about 1,700,000 gallons per twenty-four hours by pumping, and during the last few years the water was elevated by means of the air lift to a pumping reservoir from which two three-million-gallon compound condensing direct acting pumps pumped the water into a standpipe 80 feet high, which usually supplied the distribution system by gravity. The water was highly charged with soda, and therefore objectionable

for manufacturing and culinary use, although highly prized by many for drinking and bathing purposes. The yield of the wells, however, was so deficient that for the last five or more years of their operation the general practice was to furnish full service and pressure during only portions of each day. This was so unsatisfactory that many of the inhabitants depended entirely upon rain water cisterns for their supply of water.

A typical analysis of the best of the artesian well waters is as follows, all in parts per million:

Organic matter and water of crystallization,	29.7
Carbonate of iron,	5.7
Sulphate of lime,	7.6
Sulphate of magnesia,	2.8
Chloride of magnesia,	4.0
Chloride of sodium,	195.0
Carbonate of soda,	810.0
Nitrate of soda,	9.5
Silicate of soda,	43.2
Silica,	6.2
Total solids,	1113.9

The strata passed through consisted of about 430 feet of tertiary formation, 250 feet of shelly marl, and the balance down to 1955 feet cretaceous formations of various character.

The 1260 foot well previously mentioned,—viz., that at Wentworth Street,—is even at this day prized very highly for its potable qualities. In parts per million, however, the total solids are 2320—the bicarbonate of soda 1220, and the sodium chloride or common salt 1085.

As before stated, the question of a new and adequate water supply has been agitated for many years, and as far back as 1850 from time to time the Edisto River has been considered by many as the only source from which an ample supply of water, sufficient for the city's needs, could be secured. In fact there are even now many people in Charleston who are so biased in favor of the Edisto River as the only possible supply of ample quantity and pure quality that positive proof to the contrary would be unavailing. Various plans for obtaining the Edisto water at a cost within the possibilities of the estimated revenue obtainable were proposed, but none of these was found feasible up to 1899, when the city employed Mr. J. L. Ludlow, M. Am. Soc. C. E., to make surveys and determine the facts in the case. After

surveys, preliminary plans, and estimates of cost were made, the city, whose finances were at that time such as to make it impossible to undertake the entire expenditure required by itself, invited reputable contractors to investigate the conditions and present some plan whereby the new water supply could be introduced either independently or in conjunction with the old Water Company. Up to this time no consideration had been given to any surface supply closer to the city than the Edisto River. It was then that the American Pipe Manufacturing Company of Philadelphia became interested and sent the writer to investigate and report on the possibilities.

It was found that the Edisto River at Givham's Ferry, the nearest suitable point, was approximately 38 miles from the City Hall. The drainage area above Givham's Ferry is approximately 2500 square miles. Elevation of water surface 36 feet above tide datum. Water highly colored by cypress swamps. To erect the necessary Water Works to afford a daily supply of five million gallons was found to be prohibitive in cost, unless a cement lined gravity ditch were substituted for the required 30″ cast iron, steel, or wooden pipe. Even with a gravity ditch there would be required at least eight miles of pipe line or wooden flume, and the flume had serious objections of fire, depreciation, etc., and even a combined ditch and pipe line was not satisfactory to the Trust Companies.

It was then determined that unless a nearer and less costly supply could be obtained, the project would have to be abandoned.

Between the Edisto River and Charleston lies the watershed of the Ashley River. The drainage area above Bacon's Bridge, the upper limit of ordinary tide fluctuation, is about ninety square miles. The elevation of the water at this point is ordinarily about six feet above tide datum. The water, like that of the Edisto River, is high in color, due to the extensive swamps on its watershed. From Bacon's Bridge to Charleston City Hall is approximately twenty-four miles. Investigation indicated the water supply to be ample, and in case of shortage, the expense of pumping the Edisto water over the divide into the Ashley drainage basin would be small, and then if the level were raised four feet at Bacon's Bridge, an immense quantity of water could be stored. However, the expense of going to the Ashley River was found to be prohibitive.

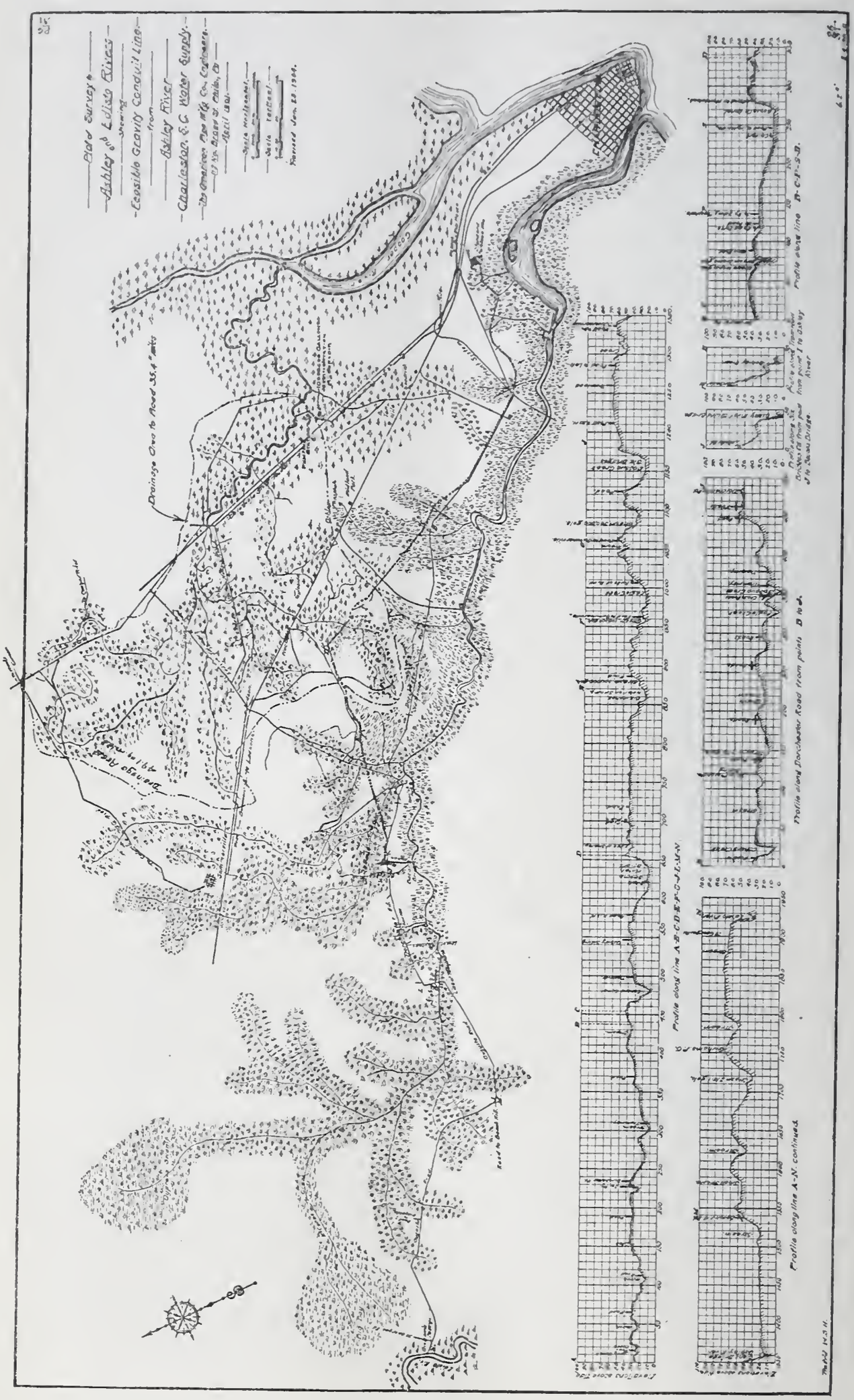
The next supply considered was that of Goose Creek, which rises some twenty-five miles northwest of Charleston and flows southeasterly into Cooper River. The drainage area above the Atlantic Coast

Line Railroad crossing, the upper limit of tide fluctuation, is about thirty square miles, and the elevation of the water at this point is about five feet above tide datum, and its character is entirely similar to that of the Ashley River. From this point to the Cooper River, the stream is very tortuous, and it is bordered alternately on one side or the other by a gradually widening extent of treeless alluvial deposit, covered with a dense growth of reeds. Opposite Saxon's Crossing, five miles down stream from the Atlantic Coast Line Railroad crossing, the marshy flat is 2500 feet wide, and the stream proper is about eighty feet wide and has an extreme depth of twenty feet. On each side of the flat the soil is composed of sandy clay. The alluvial deposit in the flat is grayish black and of a peaty nature highly charged with sulphur, and has an average depth of about nine feet at the site of the present dam, increasing to twenty feet a mile up stream, and underlaid with ten or more feet of fine sand lying on a marly deposit. At Saxon's Crossing the general elevation of this flat is about 5.2 feet above tide, which fluctuates between 2.3 and 6.5 feet, although some extreme tides have risen to an elevation of nine feet above datum. The drainage area of Goose Creek is generally composed of pine forest growth with swamps of various growth bordering each of the upper branches of the main stream. The population is very sparse, and a large proportion of the watershed is kept as a hunting preserve by the Otranto Club.

Sanitary analyses of the waters of the three streams are as follows, all in parts per million:

Total solids (at 100° C.),	80.0	52.0	70.2
Loss on ignition,	35.9	25.8	34.7
Alkalinity in terms of calcium carbonate,	20.1	10.0	15.3
Chlorine,	10.0	5.0	8.9
Actual ammonia,	0.026	0.024	0.018
Albuminoid ammonia,	0.332	0.242	0.366
Nitrogen as nitrates,	None	None	None
Nitrogen as nitrites,	None	None	None

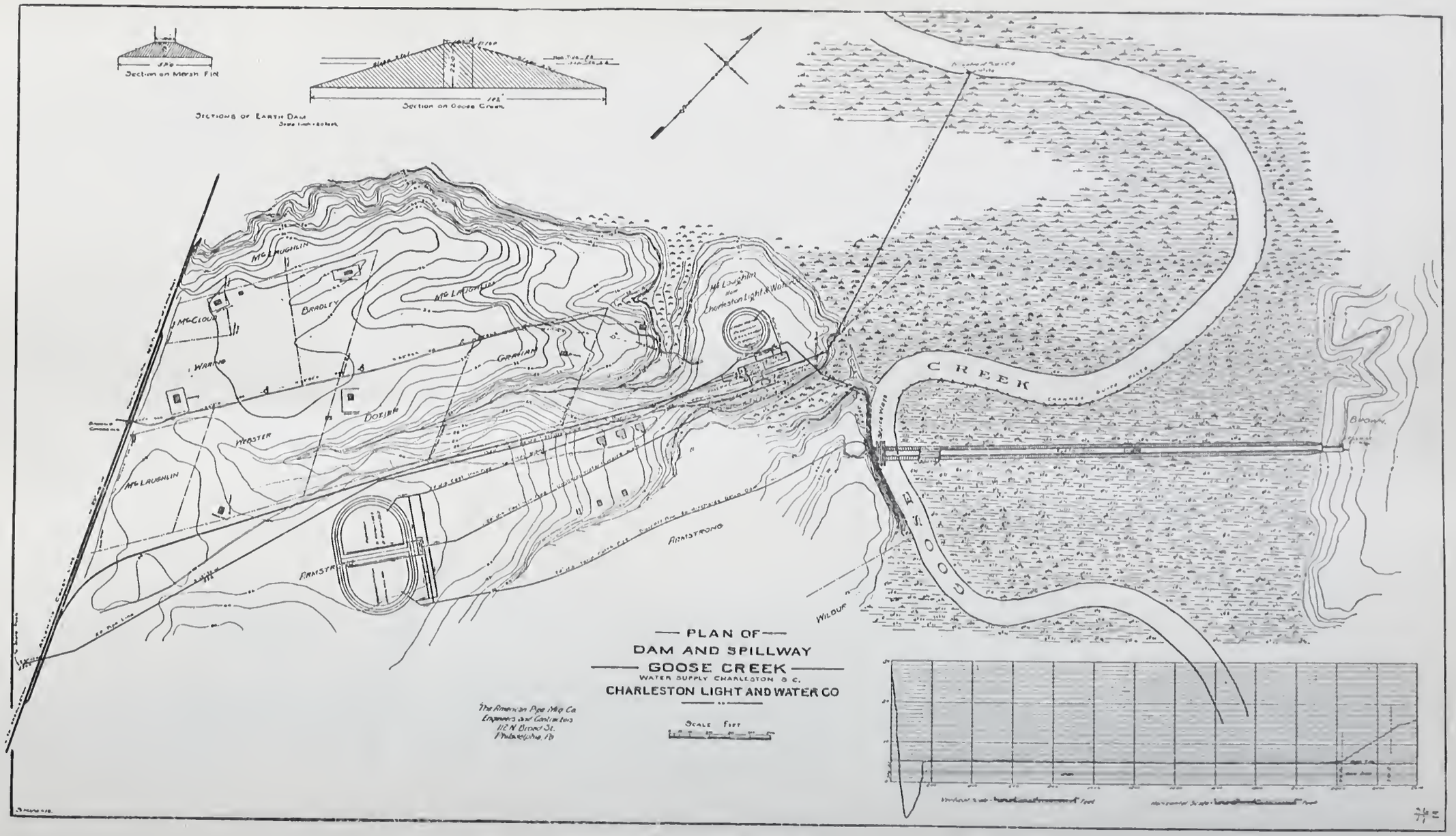
It will be seen from the analyses of the samples which were collected in February, 1901, that the three waters are not essentially different, the Edisto being the best although the hardest to filter. These waters resemble in quality and appearance those of the Dismal Swamp and Lake Drummond, Va., which are highly and universally prized as healthful by the people in that vicinity, and by mariners.


Plot Survey
Ashley & Edisto Rivers
Showing
Possible Gravity Conduit Line
from
Ashley River
Charleston, S. C. Water Supply
Drainage Area to Road 35.4 sq. miles
Profile along line A-B-C-D-E-F-G-H-J-K-N.
Profile along line A-N. continued.
Profile along Dorchester Road from point B to A.
Profile along line B-C-F-S-D.

PLAN 26–31.

Plan Number $\frac{26}{31}$ shows the relative positions of Goose Creek and its tributaries, the Ashley and Edisto Rivers, and the City of Charleston. It will be seen how close the Edisto River is to the head waters of the Ashley River, also that the distance from Bacon's Bridge on the Ashley River to the head waters of Goose Creek is only about four miles. As well as the great saving in cost, the advantages of going to Goose Creek for a water supply as against either to the Ashley River or to the Edisto will be seen. If the Edisto or Ashley were taken there would have to be two pumping stations constantly maintained, the one at the source of supply and the other near Charleston, because the pumping main would be too long for dependence on direct service in case of a serious conflagration; therefore, in either of the other supplies it has always been considered necessary to construct a reservoir at a point outside and close to the city limits. A pumping station near Saxon's Crossing at Goose Creek was deemed close enough to make the two pumping stations unnecessary. Again, if one of the pumping stations were located at either the Edisto River or the Ashley River, there would be no railroads within six or seven miles, and at times of freshet, the intervening swamps would contain four or five feet of water, and at least the Ashley River pumping station would be inaccessible except by boats. The Goose Creek pumping station has a railroad siding and is within half a mile of the Atlantic Coast Line Railroad, and one and one-half miles of the Southern Railroad at Ten Mile Hill. Then again, in case the supply of water in Goose Creek were found to be inadequate, water could be pumped from the Ashley River over the Goose Creek divide within a distance of about four miles, and in case the combined supply of Goose Creek and the Ashley River were found to be inadequate, water could be pumped from the Edisto River over the divide into the Ashley drainage area within a distance of about one and one-half miles, and in turn pumped into the Goose Creek watershed from Bacon's Bridge on the Ashley River, so that it is possible, when required, to obtain an unlimited supply of water from the Goose Creek location.

In the early investigations the writer saw nothing to indicate that the Ashley River or Goose Creek would yield in the dry season an abnormally low flow. These impressions were strengthened by the knowledge of fairly high annual rainfall (about 52 inches), heavily wooded watersheds with soil of sandy nature and a maximum elevation of the Ashley watershed about 75 and the Goose Creek watershed about 60 feet above tide. The rainfall too is highest during


Section on Marsh Fill
Sections of Earth Dam
Section on Goose Creek
McLaughlin
McLaughlin
McLaughlin
Bradley
McCloud
Warne
Graham
Doijen
Hyatt
McLaughlin
Armstrong
Armstrong
Wilbur
Brown
Goose Creek
Charleston Light & Water
PLAN OF
DAM AND SPILLWAY
GOOSE CREEK
WATER SUPPLY CHARLESTON S. C.
CHARLESTON LIGHT AND WATER CO
The American Pipe Mfg. Co.
Engineers and Contractors
112 N. Broad St.
Philadelphia, Pa.
Scale Feet

PLAN 36–17–E.

the season of greatest evaporation; but there were persistent rumors that the streams both became dry, and some of the most reputable citizens shared this view, and therefore the plan of taking water from Goose Creek contemplated this possible contingency, to provide against which, either water could be stored or the Ashley River could be pumped over the divide and if necessary the Edisto; so it was decided that in any event, as far as an adequate supply of water is concerned, no serious risk could be taken in adopting Goose Creek near Saxon's Crossing as a location for the pumping station and intake.

There were difficulties however connected with the location near Saxon's Crossing. Legally, the stream was navigable up as far as the Atlantic Coast Line Railroad crossing, and besides, during a portion of each day the stream was highly saline for several miles above the proposed intake. These two difficulties were met by a proposed dam to be constructed with its water crest above extreme high tide, and a lock to meet the Government regulations. It was assumed that the water would become fresh enough for use within a very few months after the dam was closed. The following table shows the variation of salt in the water during a tide period and when the stream was flowing at a normal rate:

CHLORINE, APRIL 18, 1902.

Time.	*Chlorine, Parts Per Million.*	*Remarks.*
8.00	A.M.....4100	....
8.20	" 4500	High tide.
9.00	" 4125	....
10.00	" 3500	....
10.45	" 3250	....
11.30	" 2400	....
12.00	Noon 2500	....
1.00	P.M.,....2125	....
1.30	" 2000	....
2.00	" 1850	Water distinctly brackish taste.
2.20	" 1625	Low tide.
3.00	" 1500	Water tastes slightly brackish.

During the low flow of the stream the water was salty all the time, the chlorine being four thousand or more parts per million. Water begins to taste brackish at 1200 parts per million.

On account of the practical advantages of the Goose Creek location, and the impossibility of obtaining either the Edisto or Ashley River supply directly by any known plan, it was finally decided to take the water supply from a point on Goose Creek opposite Saxon's Crossing

on the Atlantic Coast Line Railroad. This point is approximately twelve miles from the City Hall. A new company was formed, known as the Charleston Light and Water Company, which purchased the works of the old Water Company and made a contract with the city, dated July 1, 1902, to supply it with water for a period of 30 years. Some of the local financiers, the Mercantile Trust and Deposit Company of Baltimore, and The American Pipe Mfg. Company financed the new project, and the contract for designing and building the works was awarded to The American Pipe Mfg. Company. The works were begun the latter part of 1902 and substantially completed in the fall of 1903, and water was pumped into the city in January, 1904.

A brief description of the water works plant as actually built is now given. Referring to plan $\frac{36}{17}$–E it will be seen that a low earth dam has been built across Goose Creek where the stream hugs the south bank; the marsh is somewhat over 2,000 feet in width. Originally there was a lock proposed to be built in the dam to take care of the legal rights of navigation, which, however, was insignificant in amount, there being only several rafts of logs per year passing down stream, and an occasional small boat or naphtha launch visiting the grounds of the Otranto Club, located some five miles above the dam.

With the consent of the City Council and a special act of the State Legislature, this lock was finally eliminated to the benefit of all parties concerned.

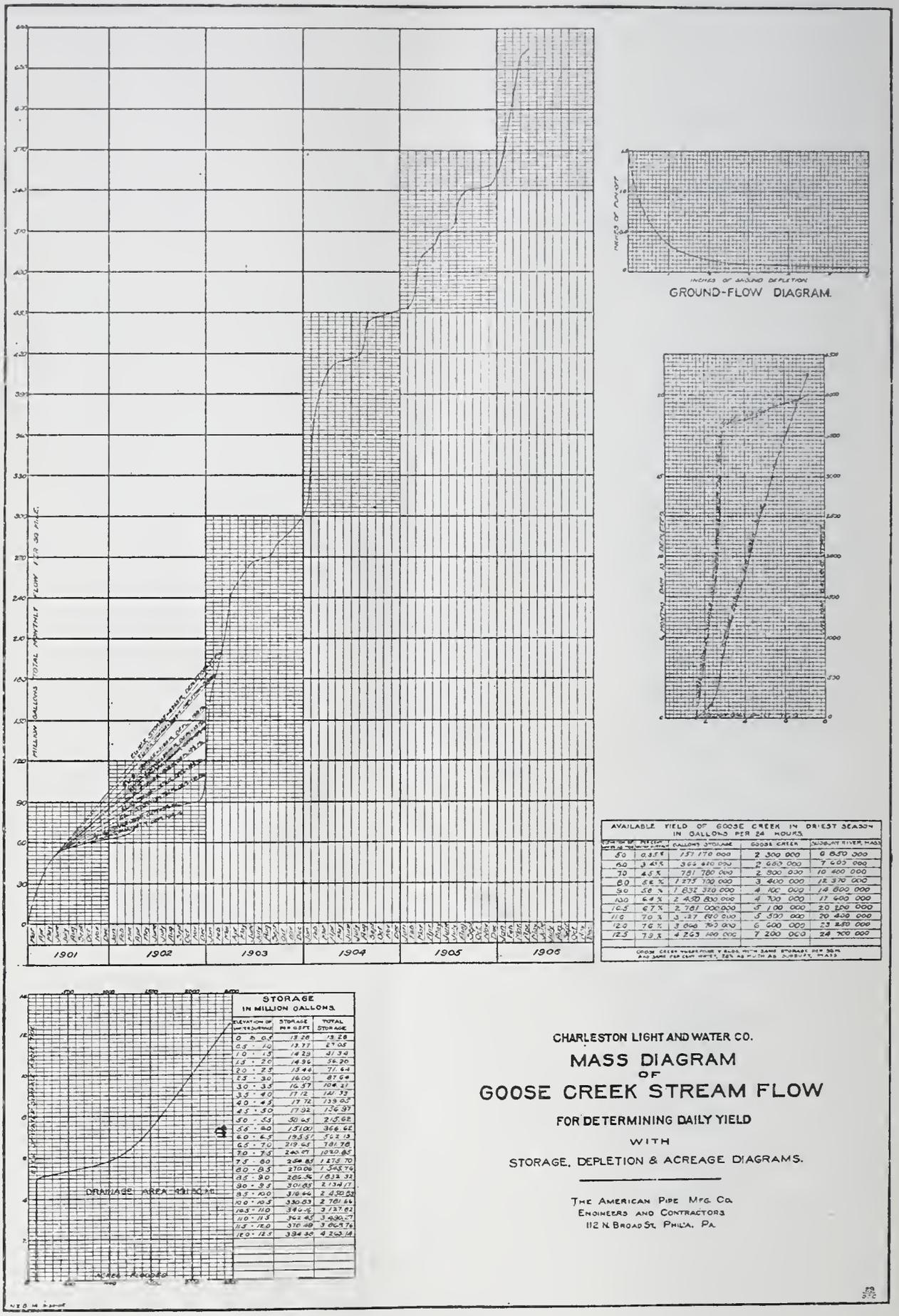
It will be seen that there are two spillways, each one hundred feet wide and permitting a depth of two and one-half feet of water. There are also two sluiceways located at the south end of the dam, one being five feet in width and the other ten feet in width. Each sluiceway is provided with two sets of gates, one to hold the up stream water and the other the possible high tides. The spillways are built of timber crib work with sheet piling extending down to solid material. The sluiceways are also built of timber, the quality being known as merchantable yellow pine. The material for the dam was taken from the south bank of the river, which was composed principally of clay of suitable quality. This material was handled and deposited by means of dump cars running on a tram road for the entire length of the dam. The marsh proved to be so soft that it required at least three times the quantity of earth fill indicated by the theoretical section of the dam, and drill holes sunk into the center of the finished embankment showed the clay fill to extend down to a depth

of about twenty-two feet, or some fifteen feet below the marsh level. This resulted in causing the marsh to rise up in waves, the outer slopes of which were at least fifty feet away from the edge of the embankment on each side; these waves, however, nearly disappeared a year after the embankment was completed. The slopes of the embankment are protected from erosion by means of knot grass, which on account of wave action did not prove effective for the up stream slope, and hence it is proposed to cover this slope with a layer of three inch granite rip rap.

It will be seen that the intake is built about two thousand feet up stream from the dam. The elevation of the center of this intake pipe is zero according to our datum, which is 1.24 feet below the Government datum at Charleston. The intake is composed of thirty-inch extra heavy terra cotta pipe in three-foot lengths, having deep and corrugated bells. The bottom of the trench being soft, the pipes were protected from settling by means of piling. This intake was laid on a level grade and discharges into a suction well built close to the pumping station.

It will be seen by Plan No. $\frac{29}{32}$–C that the reservoir holds when full 2782 million gallons, and covers an area of 2090 acres. It backs the water for about ten miles above the dam. No attempt was made to clear the reservoir of organic matter, and even the standing timber was not removed. It was reasoned that, as in any case it was prohibitive in cost, if not impossible, to get rid of at least ninety per cent. of this organic matter, it was hardly worth while to remove that portion which was plainly visible to the eye, and hence entire dependence was placed upon the effect of coagulation, aeration, sedimentation, and filtration, to purify the water. In this respect experience has fully justified our conclusions.

The pumping station is built of brick with cement floor, steel roof trusses and slate roof; the smoke stack was built by the Alphons Custodis Company according to their regular design. The pumping machinery consists of duplicate cross compound fly wheel pumping engines, each having a capacity of five million gallons per twenty-four hours, manufactured by the Snow Steam Pump Works; also a triple expansion duplex pump having a capacity of three million gallons per twenty-four hours, of the Worthington type; also two triple expansion low service duplex pumps of the Worthington type, each having a capacity of five million gallons per twenty-four hours. The three high service pumps were designed for a fire pressure of 125 pounds



AVAILABLE YIELD OF GOOSE CREEK IN DRIEST SEASON IN GALLONS PER 24 HOURS				
Elevation of water surface	Percent of time	Gallons storage	Goose Creek	Shoshuan River, Mass
50	0.35 %	151 170 000	2 300 000	6 850 000
60	3.45 %	365 810 000	2 600 000	7 600 000
70	45 %	781 700 000	2 900 000	10 400 000
80	56 %	1 275 700 000	3 400 000	12 370 000
90	58 %	1 832 320 000	4 100 000	14 800 000
100	64 %	2 450 830 000	4 700 000	17 600 000
105	67 %	2 781 000 000	5 100 000	20 200 000
110	70 %	3 127 610 000	5 500 000	20 800 000
120	76 %	3 866 700 000	6 600 000	23 250 000
125	79 %	4 263 100 000	7 200 000	24 700 000

Goose Creek water supply is also with same storage, per sq. mi. and same per cent water, 75% as much as Shoshuan, Mass.

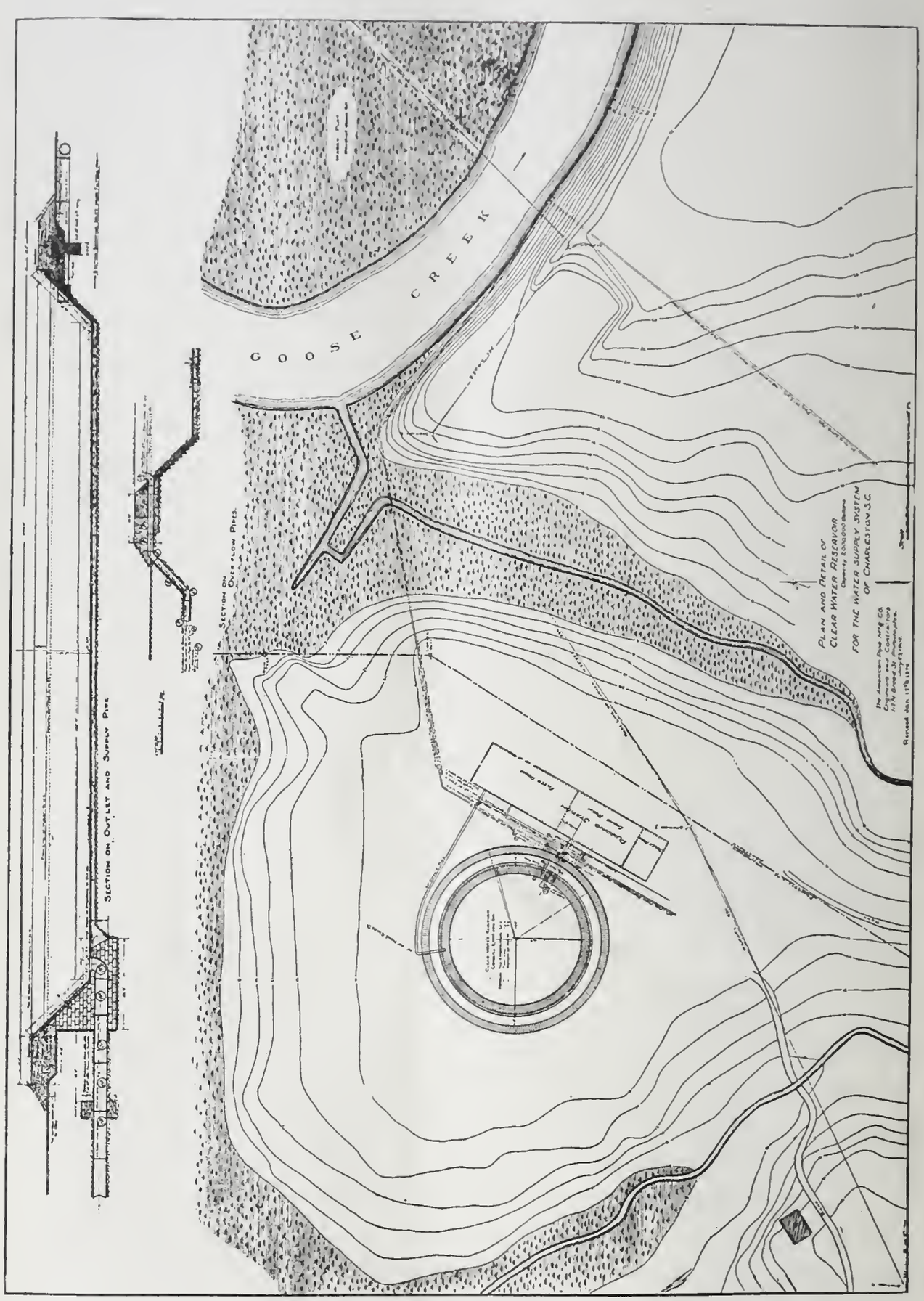
STORAGE IN MILLION GALLONS		
Elevation of water surface	Storage per foot	Total storage
0 to 0.5	13.28	13.28
0.5 - 1.0	13.77	27.05
1.0 - 1.5	14.29	41.34
1.5 - 2.0	14.86	56.20
2.0 - 2.5	15.44	71.64
2.5 - 3.0	16.00	87.64
3.0 - 3.5	16.57	104.21
3.5 - 4.0	17.12	121.33
4.0 - 4.5	17.72	139.05
4.5 - 5.0	17.92	156.97
5.0 - 5.5	58.65	215.62
5.5 - 6.0	151.00	366.62
6.0 - 6.5	155.51	522.13
6.5 - 7.0	219.65	741.78
7.0 - 7.5	240.07	1020.85
7.5 - 8.0	254.85	1275.70
8.0 - 8.5	270.06	1545.76
8.5 - 9.0	286.56	1832.32
9.0 - 9.5	301.85	2134.17
9.5 - 10.0	316.66	2450.83
10.0 - 10.5	330.83	2781.66
10.5 - 11.0	346.16	3127.82
11.0 - 11.5	362.45	3490.27
11.5 - 12.0	376.49	3866.76
12.0 - 12.5	394.38	4263.14

PLAN 29–32–C.

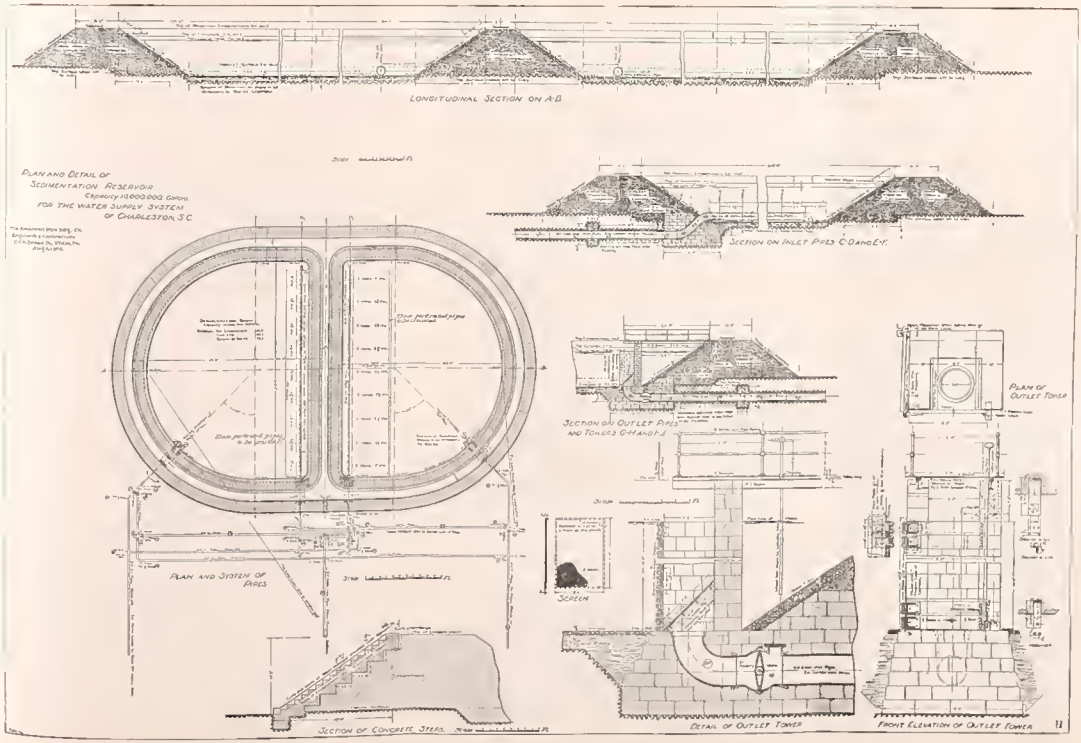
per square inch, and to run ordinarily under about sixty pounds per square inch; the low service pumps run against a total head of about thirty-three feet, pumping from the suction well to the sedimentation basin. On test, the Snow pumping engines developed a duty of 125 million foot pounds per thousand pounds of dry steam. The Worthington high service three million gallon pump developed a duty of about ninety million, and the two low service pumps developed a duty of seventy-five million foot pounds per thousand pounds of dry steam.

There are three Stirling water-tube boilers, each having 2012 square feet of heating surface. The condensers are all of the surface type. There is installed a 20 h. p. air compressor for aerating the water. Connected with the discharge main of the pumping engines, there is set in the corner of the pumping room a steel pressure air tank six feet in diameter and twelve feet high, which is completely effective to eliminate the vibrations of water pressure due to the pulsations of the pumping machinery. For the purpose of charging with air, there is attached to this air tank an ordinary Westinghouse air compressor of the type used on locomotives, and connected with the top of the air chamber and the top of each of the discharge air chambers of the several pumping engines is a three-quarter inch pipe, which enables all the air chambers to be easily charged with the requisite amount of air. This entire air cushion device we have always found to be invaluable in the operation of a pumping plant running by direct pressure, or where the discharge main is of a considerable length as in this case, being about 63,000 feet from the pumping station to the center of the city. Each of the pumping engines is equipped with a suction air chamber of ample size.

The filter plant was built by the New York Continental Jewell Filtration Company, and has a capacity of five million gallons per twenty-four hours, consisting of ten cypress tanks, operating platform, agitators, Weston controllers, loss of head gauges, and usual accessories. The coagulent consists of sulphate of alumina which is pumped into the discharge main from the low service pumps to the sedimentation basin. A portion of the time the alkalinity of the raw water is sufficient so that no other coagulent is required, but during the greater part of the year the alkalinity runs below twenty parts per million, when it is necessary to treat the raw water with lime, and for this purpose a lime building with the necessary tank and accessories is located close to the suction well and the lime water gravities into the intake pipe just before it reaches the suction well. Usually it requires about three or four grains of sulphate of alumina, per gallon


GOOSE CREEK
SECTION ON OUTLET AND SUPPLY PIPE
SECTION ON OVER FLOW PIPES
PLAN AND DETAIL OF
CLEAR WATER RESERVOIR
FOR THE WATER SUPPLY SYSTEM
OF CHARLESTON S.C.

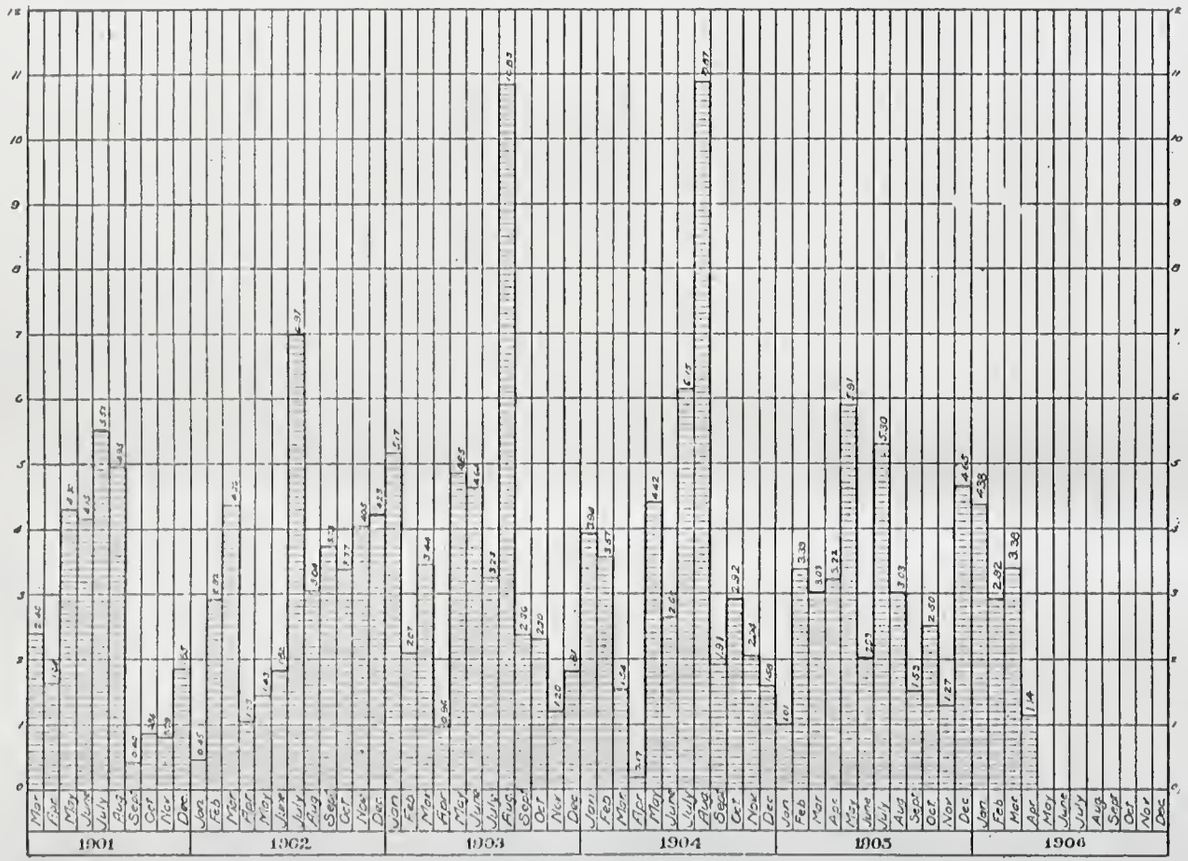
PLAN 29–13–A.


Longitudinal Section on A-B
Plan and Detail of
Sedimentation Reservoir
Capacity 10,000,000 Gallons
for the Water Supply System
of Charleston, S.C.
Section on Inlet Pipes C-D and E-F
Section on Outlet Pipes and Tower G-H and I-J
Plan of Outlet Tower
Plan and System of Pipes
Screen
Section of Concrete Steps
Detail of Outlet Tower
Front Elevation of Outlet Tower
11

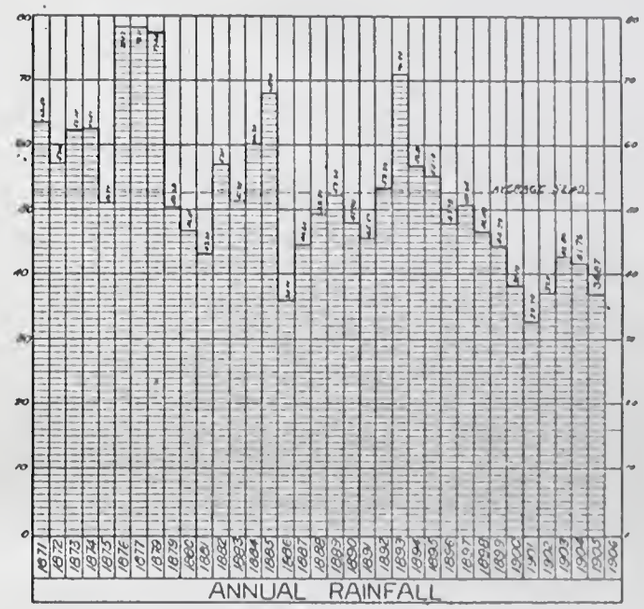
Plan 29–14

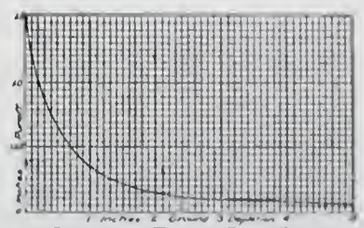
and when required about one-third of a grain of lime per gallon, the color of the raw water being reduced from 230 to 15 parts per million. At least seventy-five per cent. of the purification of the water is effected by the sedimentation basin. Water is pumped through a 24″ main to one side of the sedimentation basin, and from the other side it passes through a second 24″ main to and through the filters and into the opposite side of the clear water basin, and is drawn from the near side through the 36″ suction pipe of the main pumping engines, and thence pumped through the discharge main to the city distribution. Plan $\frac{29}{14}$ shows clearly the construction of the sedimentation basin which has a total capacity of ten million gallons, and in plan $\frac{29}{13}$—A is shown the clear water basin which has a capacity of one million gallons. It is seen that the elevation of the flow line of the sedimentation basin is 43.5 and the elevation of the flow line of the clear water basin is 17.0, the floor of the pumping station being the same level. The elevation of the top line of the filters is 33, and the elevation of the operating platform is 30. The elevation of the city streets is about three or four feet lower than the ground at the pumping station, so that ordinarily, when pumping at the usual rate of consumption, viz., about 400,000 gallons per 24 hours, the average pressure on the high service pumps is about sixty pounds per square inch, which maintains a pressure of about fifty-five pounds in the center of the city. From the pumping station to the city there is a 24″ pumping main, and the city contains about 43 miles of service mains, the sizes ranging from 6″ to 24″ in diameter. The 24″ pumping main is provided with automatic air valves on all summits, gate valves about a mile apart, and blow-off valves at depressions. All these are marked by means of square wooden posts six inches in diameter, painted white, extending about two feet above the ground and having painted thereon the designation and the distance and direction thereto.

The hydrology of the territory along the coast in the vicinity of Charleston affords very unusual conditions. By an examination of the monthly rainfall, especially for the driest years, it will be seen that there are distinctly two dry seasons per year, one commencing usually the latter part of February and ending some time in July, and the other commencing the latter part of August and ending some time in December or January. In fact the dry season would last from the latter part of August clear through the winter season until July if it were not for the low temperature of the months of January and February; while the rainfall is not high for these months, it is nearly always higher than the evaporation, or losses for the same months.



MONTHLY RAINFALL IN INCHES





GROUND-FLOW DIAGRAM

Month	Rainfall "R" Run-off Varnuda's formula multiplied by a coefficient to produce observed results	Evaporation from Water Surface * Observed * Computed	1904	1903	1906
Jan	0.31 + 0.137 r	* 2.5		1.01	2.42
Feb	0.411 + 0.137 r	2.5		2.34	3.10
Mar	0.650 + 0.137 r	3.5		4.36	4.76
Apr	1.19 + 0.137 r	5.5		5.55	5.11
May	2.56 + 0.274 r		7.00	6.02	
June	3.45 + 0.343 r		0.05	6.34	
July	4.11 + 0.411 r		6.11	5.36	
Aug	3.59 + 0.343 r		6.22	6.21	
Sept	2.50 + 0.274 r	3.2	5.18	4.58	
Oct	1.205 + 0.164 r	4.3	4.22	4.50	
Nov	0.905 + 0.137 r	4.0	2.66	2.06	
Dec	0.335 + 0.131 r	3.0	2.59	2.49	

CHARLESTON LIGHT & WATER CO.

CHARLESTON, S.C. RAINFALL DIAGRAM

AND

GOOSE CREEK GROUND-FLOW DIAGRAM

Deduced from Rainfall, Evaporation & Run-off

American Pipe Mfg. Co.
Engineers and Contractors
112 S. Broad St. Phila. Pa.

N.T.B. 21 9-6-04

566

PLAN 29-32-B.

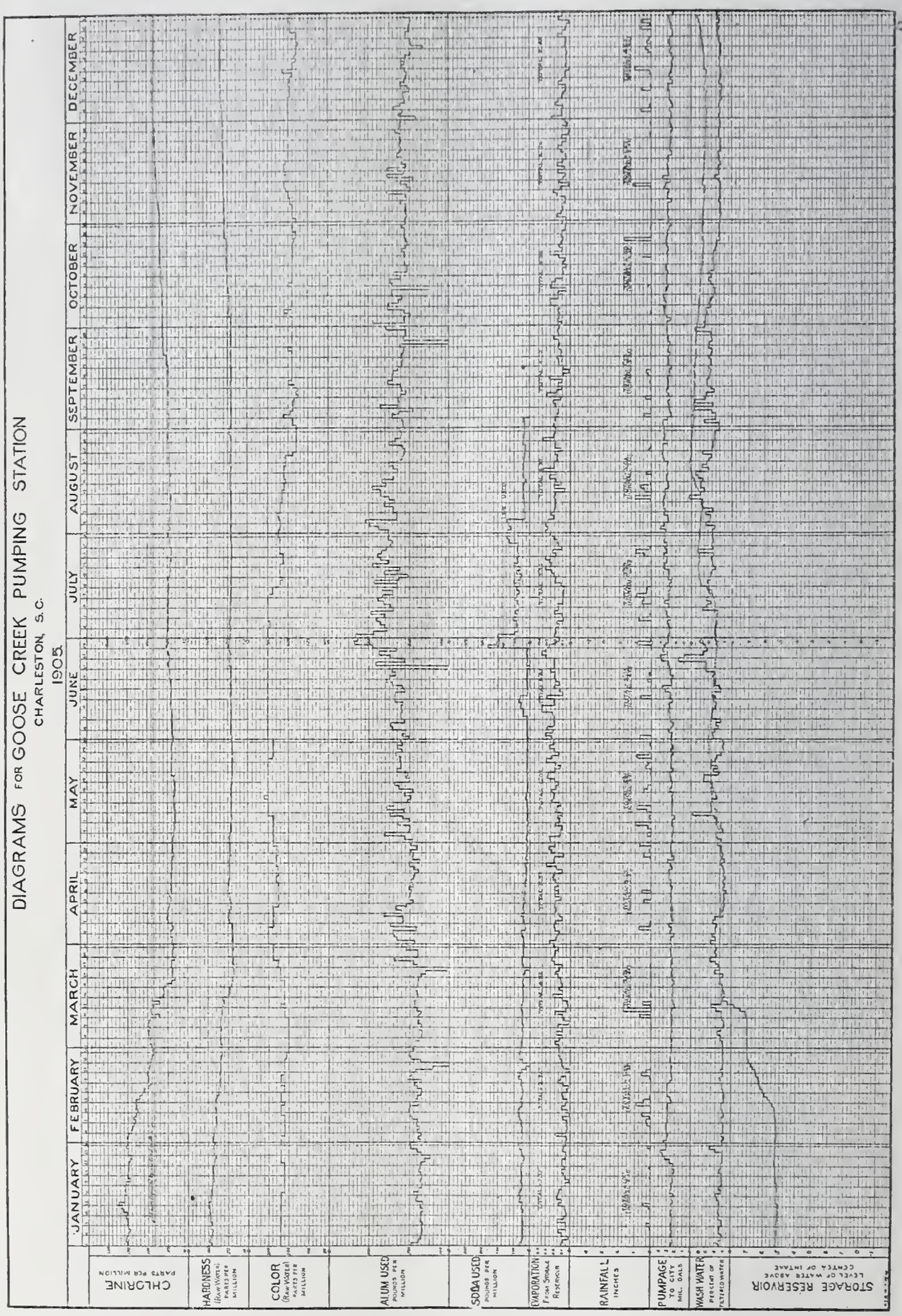
It will also be seen by an examination of the annual rainfall that while the average is about 52 inches, the rainfall for a low five year period would not exceed 37 inches. As the temperature is high especially during the months from April to October, when it is constantly warm with practically no intermission, the larger rainfall for the months of July and August does not produce the beneficial effect it would two or three hundred miles farther north where the temperature is lower.

In Charleston and vicinity the rainfall has been kept in a way for about 180 years, but the Government observations date back only to 1871, and it will be noted by an examination of the diagram shown on plan $\frac{29}{32}$–B that the annual rainfall appears to be decreasing. This fact is so marked as to warrant the suspicion that some natural phenomenon was responsible for the result. The great earthquake which so seriously injured the city occurred in the summer of 1886, and while this was a year of unusually low rainfall,—viz., 35.4,—the diagram shows that this was not the time when the annual rainfall began to decrease in a more or less regular manner. The chances are that this cycle of decreasing rainfall has reached the low point of the curve. The years commencing in 1900 and dating up to the present time are the lowest on record, the average being 38.23 inches per year for six years. This is a most unprecedented condition for a territory where the average rainfall is about 52 inches per year.

It will be noted also that the annual evaporation from water surface is thirty-seven per cent. higher than that given for this territory in the current publications, and seventy-six per cent. higher than that given for the three hottest months, viz., May, June and July. In the following table a comparison is shown between the published figures and those actually observed:

INCHES OF EVAPORATION.

	Published Figures.	*Observations on the Water Surface at Goose Creek.*
January,	2.5	2.57
February,	2.5	2.26
March,	3.5	4.36
April,	3.7	5.55
May,	3.9	7.08
June,	4.4	8.65
July,	4.5	6.77
August,	4.8	6.22
September,	4.2	5.79
October,	4.0	5.22
November,	3.2	2.66
December,	2.5	2.69
	43.70	59.82

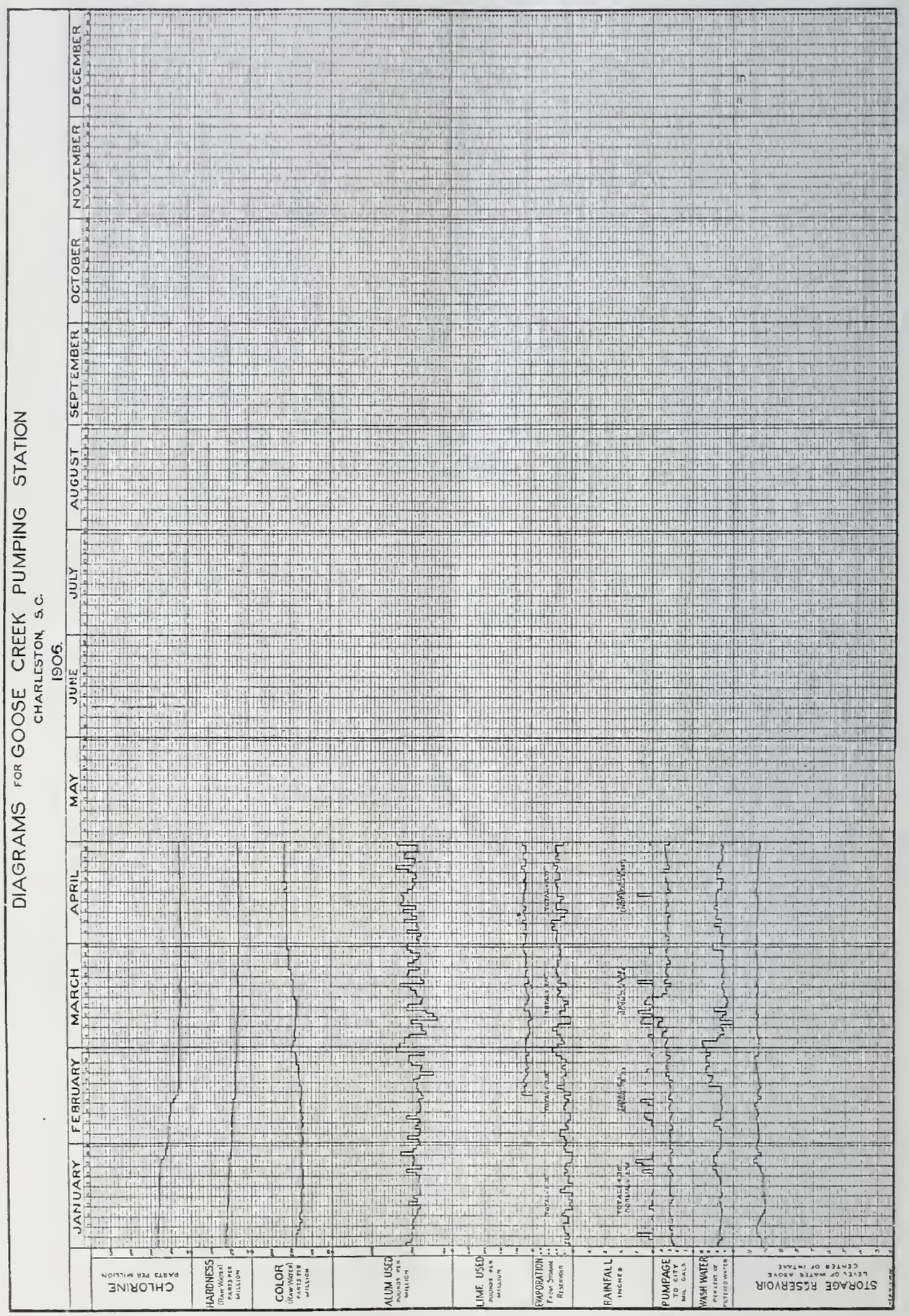

DIAGRAMS FOR GOOSE CREEK PUMPING STATION
CHARLESTON, S.C.
1905.
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
CHLORINE
PARTS PER MILLION
HARDNESS
(RAW WATER)
PARTS PER MILLION
COLOR
(RAW WATER)
PARTS PER MILLION
ALUM USED
POUNDS PER MILLION
SODA USED
POUNDS PER MILLION
EVAPORATION
FROM SMALL RESERVOIR
RAINFALL
INCHES
PUMPAGE
TO CITY
MIL. GALS.
WASH WATER
PERCENT OF FILTERED WATER
STORAGE RESERVOIR
LEVEL OF WATER ABOVE
CENTER OF INTAKE

PLAN 29-34-A.

The observed figures are for the year 1904, from May to December inclusive, and for 1905 from January to April inclusive. This comparison shows conclusively that no reliance can be placed on calculations based on the results obtained by the wet and dry bulb thermometer, which I believe is the method on which the published figures are based. Since the spring of 1904 the evaporation from the water surface of the dam has been observed daily, the figures being shown on plans $\frac{29}{34}$-A, $\frac{29}{34}$-B and $\frac{29}{32}$-B.

It will be seen by the table in plan $\frac{29}{32}$-C that with the utmost storage capable of being developed on the Goose Creek drainage area of 49 square miles, it is possible to obtain in the driest season a yield of 0.22 cubic feet per second, or about 140,000 gallons per 24 hours per square mile. On the Croton, N. Y., or Sudbury, Mass., watersheds it is possible, with maximum storage, to obtain and depend upon at least 0.9 cubic feet per second, or 600,000 gallons per twenty-four hours per square mile, and even at Norfolk, Va., where the topographical conditions are entirely similar to although not as favorable as those of Goose Creek, it is possible to obtain as much as that at Sudbury or Croton. In this table, which shows the quantity of water obtainable with various amounts of storage, the results are based on the dry period from 1900 to 1904, which is probably the most extreme drought ever experienced in that country.

When the works were first put into operation in January, 1904, the chlorine in the reservoir was about 4000 parts per million, and with the closing of the dam this rapidly diminished to about 800 parts per million, and in order to reduce the chlorine to the requirements of the contract, large centrifugal pumps were set to work pumping the water out of the reservoir so as to displace the saline water with fresh water from the upper portion of the watershed. By the latter part of February the chlorine was reduced to 85 parts per million. It was then an extreme dry season began with very little storage in the dam, and by the end of July the level of the water had reached the top of the intake pipes where it remained, however, for only a day or so, when the summer rain rapidly filled the reservoir, since which time no shortage of water has been experienced. During this period of low water the quality of the water was by no means good; the total solids, hardness and chlorine averaging high, as will be noted by the diagrams. Since that time however the filtered water has been very satisfactory, clear and odorless, but during the summer of 1905 the water developed a pronounced odor, and after a thorough investiga-


DIAGRAMS FOR GOOSE CREEK PUMPING STATION
CHARLESTON, S.C.
1906.
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
CHLORINE
PARTS PER MILLION
HARDNESS
(Raw Water)
PARTS PER MILLION
COLOR
(Raw Water)
PARTS PER MILLION
ALUM USED
POUNDS PER MILLION
LIME USED
POUNDS PER MILLION
EVAPORATION
From Storage Reservoir
RAINFALL
INCHES
PUMPAGE
TO CITY
MIL. GALS
WASH WATER
PERCENT OF FILTERED WATER
STORAGE RESERVOIR
LEVEL OF WATER ABOVE CENTER OF INTAKE

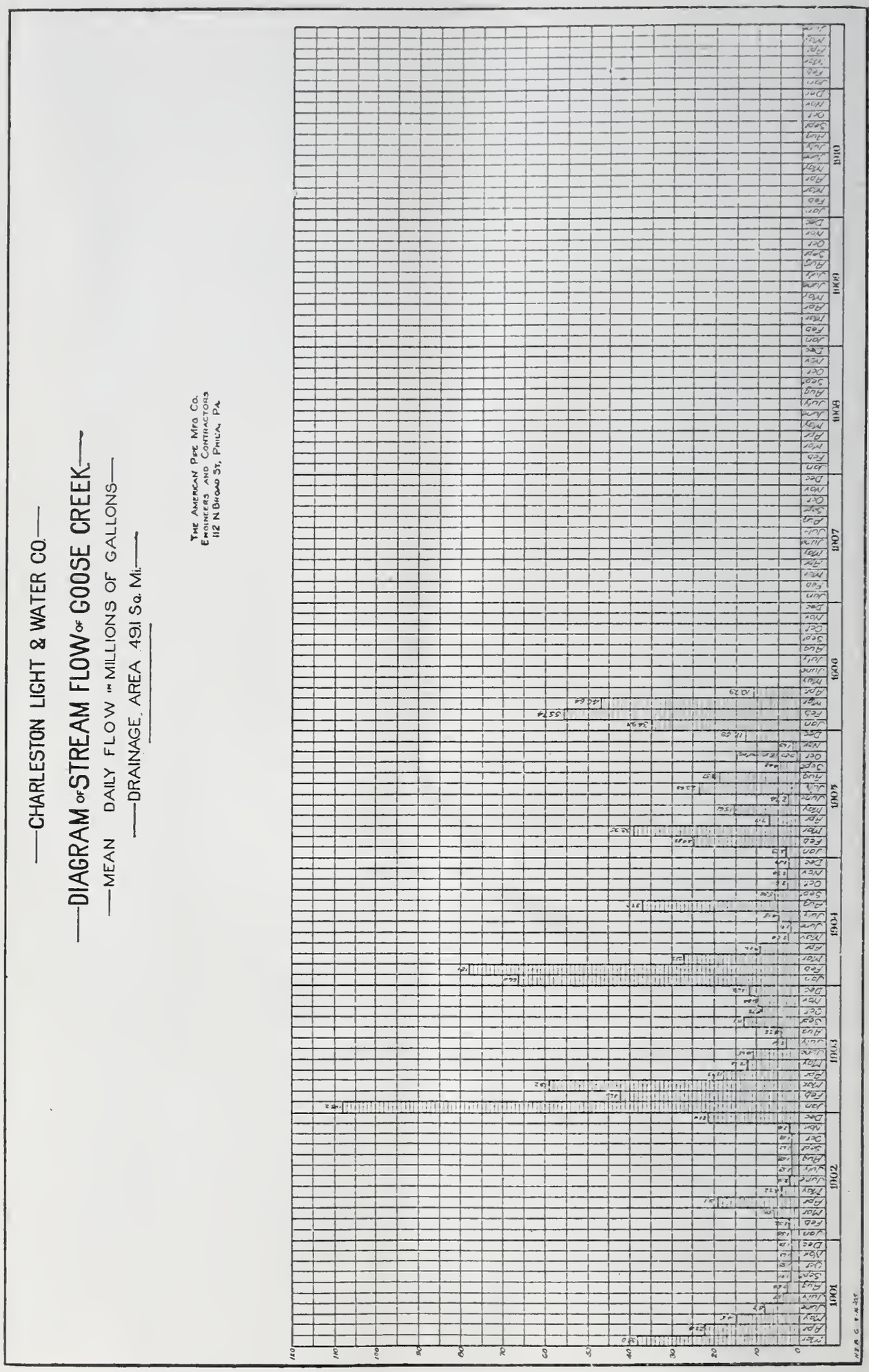
PLAN 29–34–B.

tion it was found that the raw water was entirely devoid of dissolved oxygen. Air was then snifted into the suction of the low service pumps, and within three or four days the water became again of good quality and thoroughly satisfactory. An air compressor was then installed so that the water could be aerated satisfactorily at all times. No further trouble has been experienced.

A TYPICAL ANALYSIS OF GOOSE CREEK FILTERED WATER IS AS FOLLOWS—ALL IN PARTS PER MILLION:

Total solids,	123.000
Loss on ignition,	33.000
Hardness,	33.860
Alkalinity,	6.000
Carbon dioxide Co_2,	5.000
Carbonates Co_3,	3.06
Chlorine Cl,	25.000
Nitrates NO_3,	.050
Sulphurous acid SO_3,	36.810
Silica SiO_2,	1.580
Aluminum oxide Al_2O_3,	1.020
Iron oxide Fe_2O_3,	.710
Calcium oxide CaO,	16.910
Magnesium oxide MgO,	.602
Sodium oxide Na_2O,	21.330
Potassium oxide K_2O,	.870

The contract requirements in regard to the water supply are substantially as follows: Guaranteed supply of five million gallons per twenty-four hours; ability to pump at the rate of eight million gallons per twenty-four hours in case of emergency; water to be good and potable and free from objectionable odor and taste, and suitable for manufacturing and laundry use; the filtered water to contain per million parts not more than eighty-five parts of chlorine, seventy-five parts of total solids, exclusive of common salt; forty-five parts of total hardness. The filters shall remove at least eighty-five per cent. of the albuminoid ammonia in suspension; at least eighty-five per cent. of the color by the Platinum Cobalt Standard; ninety-seven per cent. of the bacteria when the number in the raw water is over 3000 per c.c., and all but 100 when the number in the raw water is less then 3000 per c.c. Bacteriological analyses of the filtered water have been frequently taken and the filtered water at the pumping station usually contains less than 50 bacteria per c.c., while the raw water varies from 350 to 1000, the average being about 500 bacteria per c.c.


—CHARLESTON LIGHT & WATER CO.—
—DIAGRAM OF STREAM FLOW OF GOOSE CREEK—
—MEAN DAILY FLOW IN MILLIONS OF GALLONS—
—DRAINAGE AREA 49.1 Sq. Mi.—
THE AMERICAN PIPE MFG. CO.
ENGINEERS AND CONTRACTORS
112 N. BROAD ST. PHILA. PA.
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
120
110
100
90
80
70
60
50
40
30
20
10
0

PLAN 29–33–B.

It will thus be seen that whereas the problem of compliance with the city contract was by no means easy, the results obtained show that it has been solved beyond question.

Plan $\frac{26}{31}$ shows the whole territory under consideration, and the drainage area of Goose Creek.

Plans $\frac{29}{34}$–A and $\frac{29}{34}$–B show the diagrams of the various data collected since the station was put in operation.

Plan $\frac{29}{33}$–B shows the deduced flow of the stream, based on observations.

Plan $\frac{29}{32}$–C gives the storage and the mass diagram showing the methods of deducing the stream flow for other seasons than those in which the conditions are actually observed.

Plan $\frac{29}{32}$–B shows a diagram of the annual and monthly rainfall and formulas for evaporation.

Plan $\frac{36}{17}$–E is a general plan showing the location of the pumping station, reservoirs, dam, etc.

Plan $\frac{29}{13}$–A shows the intake, pumping station and clear water basin.

Plan $\frac{29}{14}$ shows the sedimentation basin.

In calculating the stream flow for years other than those for which we have actual records, the general method adopted by Mr. C. C. Vermeule, M. Am. Soc. C. E., for the New Jersey streams, has been adopted, the formulas however being deduced from the actual conditions for the periods observed.

Paper No. 1024.

A COMPARISON OF THE FIRST COST AND COST OF OPERATION OF PUMPING PLANTS DRIVEN BY STEAM AND OIL ENGINES.

FRANCIS HEAD.

Read May 19, 1906.

The City of Philadelphia recently called for bids on low-lift pumping machinery for the Torresdale Filters according to specifications under Contract No. 35.

As these specifications called for centrifugal pumps to be driven by either reciprocating steam engines, turbines, or oil engines, a comparison of the prices which were submitted, taking into consideration the various duties which were offered by the bidders, will yield some interesting comparative data relative to pumping plants.

The specifications called for six units of forty million gallons each. These were to lift the water from a conduit leading from the river and deliver it to pipes five feet in diameter, by which it was to be led to the preliminary filters. The maximum lift measured from the surface of the water to the discharge side of the pump was forty-five feet; no allowance being made for the velocity head in the water of discharge.

Each bidder was required to furnish a complete plant as far as the machinery went, including engines, piping, boilers, etc., and to operate it for six months, and to make tests of twenty-four hours and thirty days respectively to determine the duty and capacity.

For the sake of making a comparison of the values of the different types of machinery the specifications stated as follows:

"Bids will be compared on the following basis:

"The value of money will be taken at three and a half per cent. per annum. After the bids are scheduled drawings will be prepared giving the necessary dimensions for the engine and boiler rooms to house the different classes of machinery. The cost of the buildings will be computed at fifteen cents per cubic foot, measuring from the engine and boiler room floors to midway between the top of the walls and the ridge purlin; and the amount thus obtained will be used in ascertaining the cost of installation.

"In comparing the cost of operation coal will be figured at three dollars and thirty ($3.30) cents per ton of two thousand two hundred and forty (2240) pounds and fuel oil will be figured at three cents ($0.03) per gallon.

"In comparing the bids with reference to the time for starting the machinery in operation, allowance will be made at the rate of two hundred and fifty dollars ($250) per calendar day for the bids specifying earlier dates of completion as compared with the bid specifying the longest time."

In addition to this, under clause No. 118 there was provision in case of failure to meet duty guaranteed, which was as follows: "For each million foot pounds duty the pumping engines fall below the duty specified in the bid there will be deducted one thousand dollars ($1000) from the contract price for each engine."

There were three bidders on steam plants who had figured on six water-tube boilers of 312 h. p. each, all to be fitted with automatic stokers, superheaters, and economizers, the city to furnish the smokestacks and foundations.

The lowest engine bid was submitted by the R. D. Wood Company, who offered six units driven by compound condensing engines. The D'Olier Engineering Company submitted figures on eight centrifugal pumps driven by De Laval steam turbines, two units being connected to one condenser. The oil engines were offered by The American Diesel Company, who bid on six double units of 500 h. p. each and two single units of 250 h. p. each, direct connected to a 165 k. w. electric generator, this electric plant being in duplicate to operate the air compressors and having an excess of power to supply the electric crane, lighting, and power in and about the plant.

A comparison of the size of the steam plant as planned by the Filtration Bureau and the room required for the oil engine installation is shown in Fig. 1, in which the space required for the oil engines is represented by the shaded portion.

The general arrangement of the Diesel plant, showing provision for increasing the capacity of the plant fifty per cent., is shown in Fig. 2. The plans called for six units to be installed, one being in reserve, as the intention of the Filtration Bureau was to pump two hundred million gallons per day. This capacity has been used in making the comparison of the bids.

The duty guaranteed for the twenty-four-hour run by the steam engines was 85,000,000 foot lbs. per 100 lbs. of steam; by the turbines

88,000,000, and by the oil engines 95,000,000. For the thirty-day test the duty guaranteed by the steam engines was 70,000,000; by the turbines 83,000,000, and by the oil engine 90,000,000.

Forty million gallons per day against forty-five-ft. head requires 315.6 h. p. in the water column. The I. P. Morris Company,

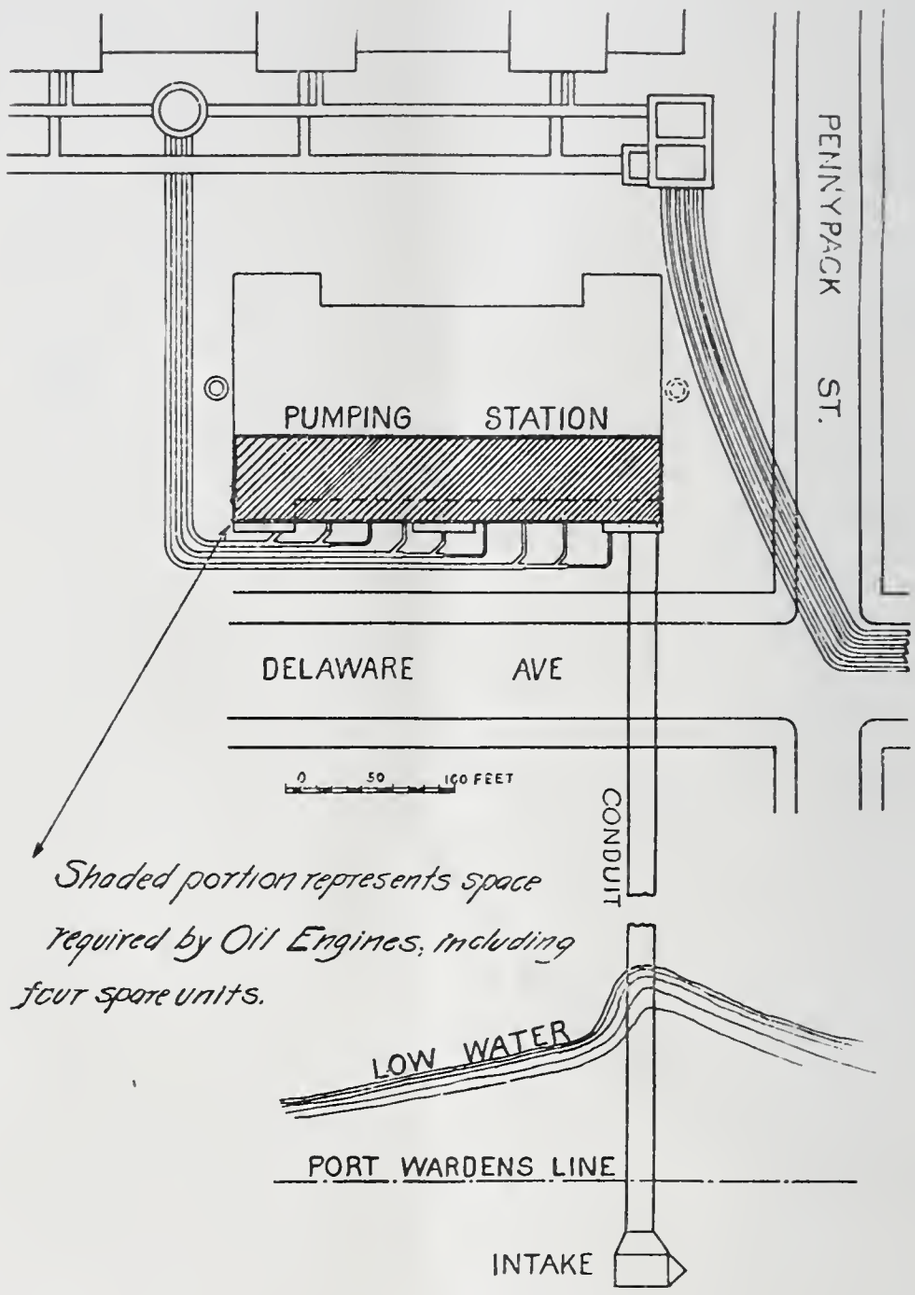


Fig. 1.

whose design for the pumps was used by the Diesel Company, guaranteed seventy per cent. efficiency under the conditions of the contract, *i. e.*, the pump shaft required 450 h. p.

For the purpose of comparison, the duty on the thirty-day test alone was used.

With the Diesel engine five gallons of oil per 90,000,000 foot lbs.

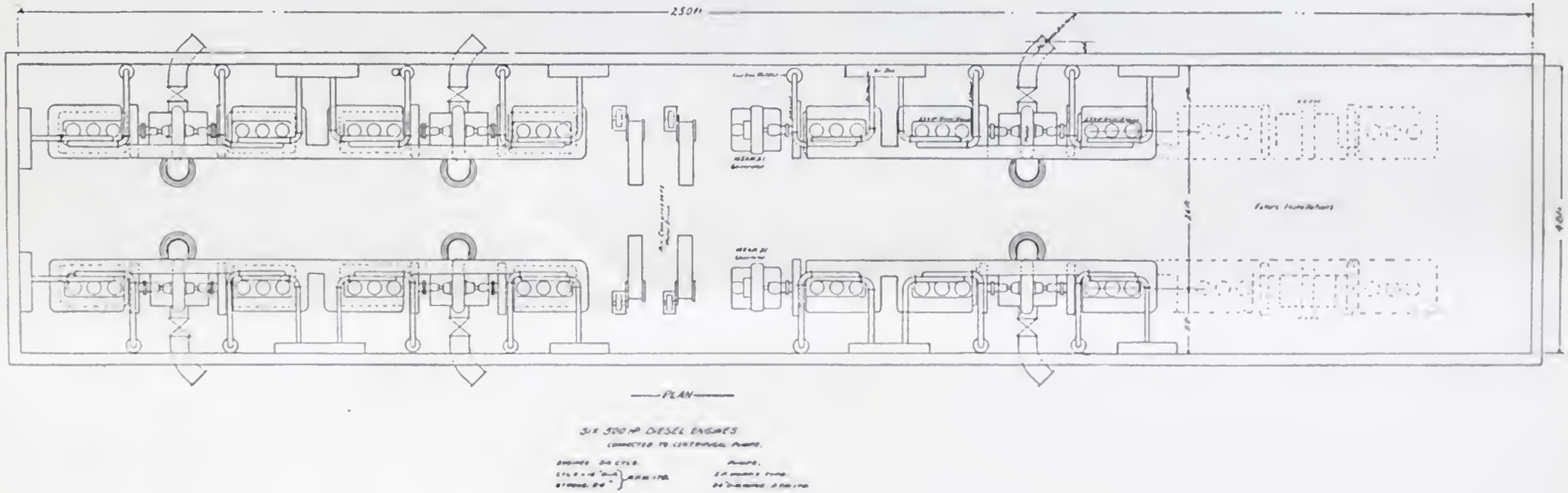
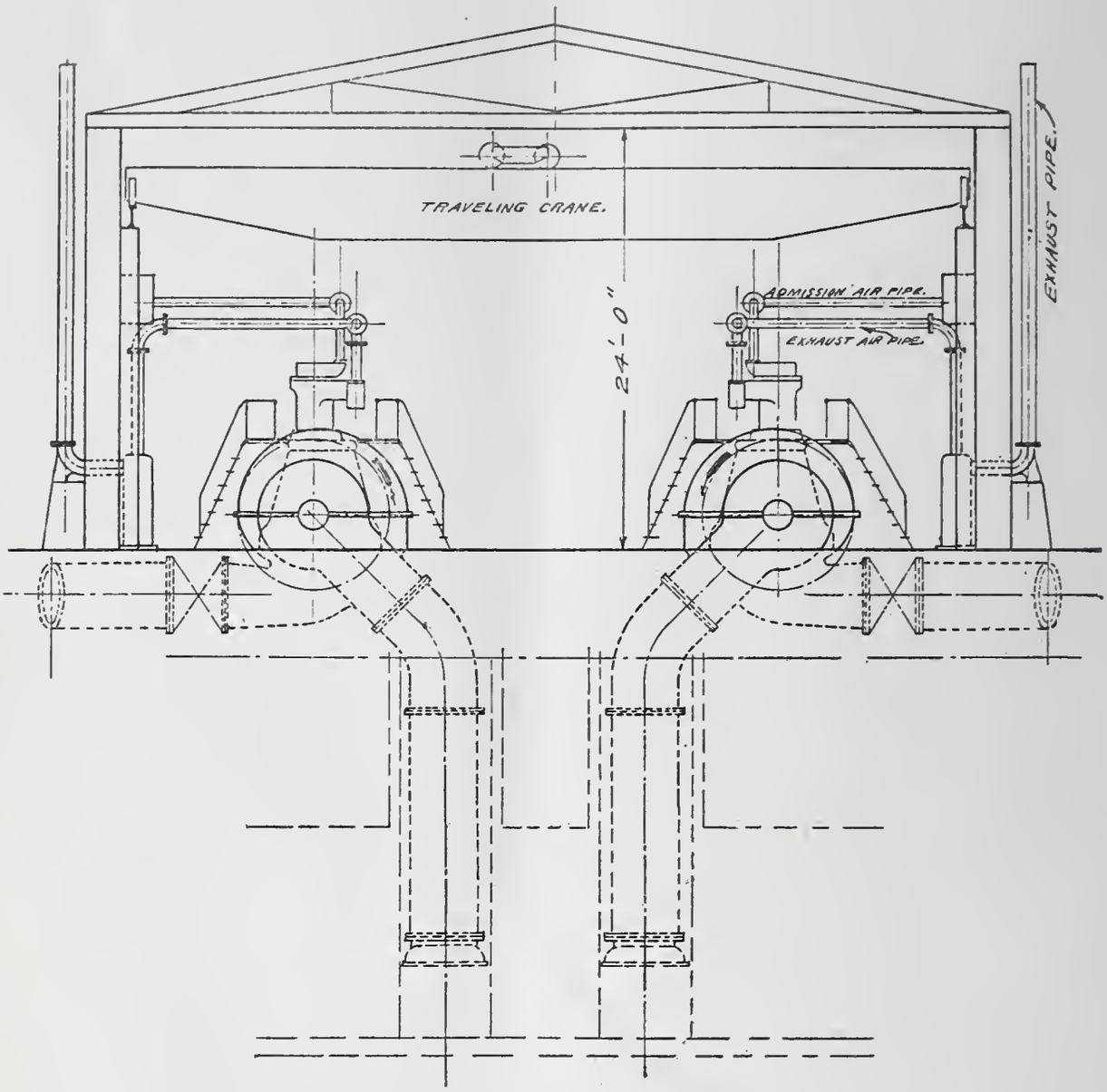


Fig. 2.

means 34.65 gallons per pump per hour, costing $1.0395, or $24.95 per twenty-four hours per unit.



SIX 500 HP. DIESEL ENGINES
CONNECTED TO CENTRIFUGAL PUMPS.

ENGINES SIX CYLS.
CYLS = 16" DIA. } R.P.M. 170
STROKE 24"

PUMPS.
I.P. MORRIS TYPE.
36" DISCHARGE. R.P.M. 170.

Fig. 3.

The coal required by the different types and the cost is as follows:

	Lbs. Coal per H. P. Hour.	315.6 H. P. Lbs. Coal per Hour.	24 Hours.	Cost per Pump per 24 Hours.
70 million duty,	2.83	893	21,435	$31.57
83 " "	2.39	753	18,072	26.63
90 " "	..	..	..	24.95

The fuel saving per pump by the oil engine over the steam units, is as follows:

	Per Hour.	Per Year.
Steam engines,	$6.62	$12,080
Turbines,	1.68	3,080

It should be further noted that each of the steam propositions emphasized the fact that the coal furnished must have 14,500 B. T. U., or if it were less, due allowance must be made, which means that these guarantees were made on a good grade of bituminous coal.

With the Diesel engine nothing but fuel oil of commerce was required.

A comparison of the bids is shown in table.

	Steam Engines.	Turbines.	Diesel Oil Engines.
Time required in days to furnish plant.	245	300	250 for half plant. 315 for whole plant.
Duty in million foot lbs. per 100 lbs. coal.	85 and 70 millions	88 and 83 millions	95 and 90 millions per 5 gals. oil.
Price bid.	$205,400	$178,000	$298,000
Extra for house.	$52,528	$60,207	...
Electric plant and stack.	$20,000	$20,000	...
Cost of plant.	$277,928	$258,207	$298,000
Extra for time at $250.00 per day.	...	$13,750	$17,500
Extra cost of coal over oil per year.	$12,080	$3,068	...
Extra cost of coal over oil per year. Capitalized at 3.5%.	$345,100	$87,650	...
Comparative price based on duty.	$623,028	$359,607	$315,500
Boiler room, labor and repairs.	$10,150	$10,150	...
Extra cost of operating steam plants per year.	$22,230	$13,218	...
Extra cost of operating steam plants per year. Capitalized at 3.5%.	$635,100	$377,650	...
Comparative price based on duty and labor saved.	$913,028	$649,607	$315,500

In comparing the actual cost of the plants to the city the turbine is the lowest, being $258,000; the steam engine comes next, $278,000, the oil engine being the highest at $298,000.

In making this comparison the foundations of the boilers and ash tunnels have not been included. When the extra cost of operating the steam plants over the oil engine is capitalized at three and a half per cent. in accordance with the specifications, and due allowance has been made for penalizing the oil engine and steam turbine, it will be seen that the cost of the oil engine was approximately $315,500, the turbine engines twice as much, $649,600, and the steam engines nearly three times as much, $913,000.

Under the specifications the right was reserved to accept the lowest bid of any of the particular classes and the bid shown above for steam engines was the one accepted.

Without questioning the wisdom of the above selection, it is thought that this comparison will be of interest as exhibiting the relative costs of the various types of machinery and their commercial advantages.

DISCUSSION.

President McBride.—The comparison with the steam turbine seems rather unfair to the steam engine. I do not think that the statement will be disputed that for this size unit and this head the steam engine direct-connected to the centrifugal pump will do better in steam consumption than any steam turbine combination. If, therefore, the duties stated for the steam turbine are possible under the specifications, somewhat higher duties ought to be possible with the steam engine. To compare correctly the steam engine units would require a fourth column to the table, representing units of this type which, while they might possibly have a higher first cost, would give a higher duty and therefore reduce enormously the steam engine "Comparative Price Based on Duty" and extra cost of coal over oil, etc.

Mr. Head.—There was another engine bid which offered seventy-two and a half millions duty in place of seventy millions, but as this bid did not figure out as well as the seventy million bid, it was not put in the above list.

It is fair to presume that the duties guaranteed represented the best American practice for engines of this type, as the choice of three well known makes was offered. That the duties offered by the various builders were not higher was probably due to the large penalty of $1000 per million duty, which was to be exacted for each unit which failed to make the guarantee, and also to the general impression that the thirty-day tests would be rigidly carried out.

On behalf of the steam turbine, it should be remembered that the high speed at which the impeller runs is favorable to centrifugal pump efficiency.

That the bidders on steam engines did not offer higher duties, when they were aware that the bids were to be compared on a duty basis, established the fact beyond reasonable doubt that they could not safely guarantee more than they did.

PAPER NO. 1025.

THE FOREMAN—HIS TRAINING, WORK, AND RELATION TO RAILROAD MAINTENANCE OF WAY ORGANIZATION.

S. W. KAPP.

Read June 2, 1906.

THERE were in 1905 about 293,000 miles of railroad in operation in the United States. The Maintenance of Way and Structures employees at that time numbered about 326,000. Close to 65,000 of these employees were foremen on the basis of one foreman for every five employees. Of this body of foremen—equal numerically to the present enlisted strength of the United States Army—nearly 40,000 were section or track foremen. The balance, about 25,000, had charge of other employees not trackmen, as masons, plumbers, carpenters, bridgemen, painters, signalmen, etc. Compared with the population of the United States, there is then one foreman of maintenance employees to every 1250 inhabitants. Such is the foreman under discussion in point of numbers.

As the population is made up of strains from nearly all the old world peoples, representatives of many of them are found in the large body of foremen. The Irish foreman is perhaps the type most familiar. He seems to have taken to the business of railroading more naturally than the others, whether from disposition or opportunity is not altogether clear. The stories that are told of him, his wit, and his "bulls," are many. These tales have made him the familiar type that he is. In many cases he is almost illiterate, but he usually makes himself understood. To grasp fully what this means one has but to read the reports and letters from a group of these men and come in personal contact with them. Many are pastmasters at phonetic spelling; so much so that a faithful rendering of the written word brings out the individual brogue clearly.

We are all familiar with the story of the foreman who heeded his instructions to be brief in making his reports to his superior with such aptitude that the cut diamond, "Off again, on again, gone again, Finnegan," was given to us. Almost matching this in brevity is the

telegram sent by a foreman to his superior as the result of a train having run down some stock on the track the day before, as follows: "Patrick Clancy, Roadmaster. The cow that number three killed yesterday is not dead yet, what shall I do with her. Michael Grady." In that short sentence he called attention to the previous report of the accident, gave an account of subsequent developments, and asked for further instructions. He also managed to commit an "Irish bull."

A foreman during an inspection of his territory by some of the officials representing a new management and a more liberal policy as to expenditures, was chided for the poor condition of his track in spite of extra expense incurred recently to secure improvement. He quickly made his excuse and at the same time turned the situation into a humerous one by remarking: "You should have been here when the trains were running on the shadow of the telegraph wire!" He further explained the previous conditions by alleging that had the fences not been in good shape at that time, the trains could not have been kept on the right of way.

While the Irish type is perhaps the most interesting the others are not uncommon, English, Dutch, German, Scandinavian, Italian, and African examples being frequently met with. All have their good qualities. The types other than the Irish are usually found in communities where the particular nationality is or has been a very considerable portion of the population. It is often the case that the men under a foreman are of his nationality.

Almost invariably the foreman begins his railroad career as a laborer on the lowest rung of the ladder. This is so no matter to what class of employee he belongs. Once an employee, about the first thing of which he is really made conscious is expressed by the following scene between a foreman and his men. Foreman.—"Pick up that tie!" The men pick it up. Foreman.—"Put down that tie!" The men put it down. Foreman.—"Pick up that tie!" The men pick it up. Foreman.—"Put it down again!" The men put it down. Foreman.—"Now who's boss?" This is the lesson that must be learned before any progress can be made, namely, obedience to orders. It is, of course, not necessary that the obedience be as blind as the scene just cited indicates, but this obedience is nevertheless the basis of all proper relationship between the foreman and the men under him. Once this lesson has been learned, the beginner by watching others and by direct coaching on the part of the foreman learns to do the varied kinds of work falling to the lot of his particular gang. After

working in this way for a greater or less time he has become proficient in his line, carrying each item to completion as instructed. He has, moreover, displayed an interest in his work and a tendency to act as a leader. On this account he is from time to time given charge of one or more men for odd jobs. If successful with such minor responsibilities, he is at last made a sub-foreman or assistant foreman. When he has served as an underforeman for a sufficient length of time and displayed ability in getting on with and getting results from the men under him, he is considered ready for promotion to a full-fledged foremanship when opportunity offers. This progression from laborer to foreman requires, even under favorable conditions, a considerable length of time, say from three or four years to as much as eight or ten. There are, of course, exceptions to this scheme of development, but it is practically true as far as the major portion of all maintenance employees is concerned, and it is especially true of track foremen. After going through this thorough training, he at last is considered to have learned his trade. And trade it surely is, as much so as that of the ordinary mechanic. This trade requires the knowledge of many things which comes only with long and patient experience with them and knowledge of many other things through association.

What are these things that are so difficult to master? The knowledge of the effect of temperature, wind, moisture, friction, chemical action, stress, motion of trains, and passage of time on the materials of construction and maintenance, and of the action to be taken to eliminate the effects of these ever-present agents. In addition, that almost sixth sense—railroad intuition—must be acquired thoroughly.

Expressed thus the matter does not loom up very large. It is, however, quite so. As some of these items are named, see how many you know how to combat. By this is not meant, know what to suggest to try, but is meant to know what if tried will surely answer the purpose.

Temperature.—Expansion and contraction of rail; breaking of telegraph wires in cold weather; frost heaving track unevenly; ice obstructing drainage lines; freezing of water lines and connections; breaking of rail in cold weather; the condensation of atmospheric moisture in the cups of oil lamps and on the relay and other contacts used in electric signal connections; the action of frost on exposed masonry, fences, poles, signals and signs; expansion and contraction of bodies of concrete or other masonry; formation of sleet on wires and signals; throwing down rocks in cuts; formation of ice in rock cuttings; fire in cinder banks and coal piles.

Wind.—Action on snow; on sand; on both mixed; on bodies of water; on floe ice; on fences, poles, signals and signs; on trees along the tracks; on fire on or near the right of way.

Moisture.—High water in large and small streams; cutting of embankments by current; undermining of masonry; softening of roadbed; landslides in cuts and on embankments; formation of ice jams; springs in cuts and under the roadbed; decreased insulation on wire lines for telegraph and signals.

Friction.—Surface and curve wear of rails; the cutting of rails into cross-ties and switch-ties; the cutting of spikes against the rail; the wear of switches and frogs; the wear of parts of an interlocking; ice or frost forming under the rails, decreasing the frictional resistance to spreading, and throwing more pressure against the spike.

Chemical Action.—Action of salt air, and salt water from refrigerator cars, on rails, splices, spikes, bolts and fittings; on bridge iron, and paint also; effect of locomotive gases on structures; care and maintenance of primary and storage batteries.

Stress.—Deterioration of iron and steel structures under vibration and loading; creeping of rails from wave motion under traffic; creeping and pulling of rail under changes of temperature; deterioration of rail, frog, and switch fastenings under vibration and stress.

Movement of Trains.—Line and surface of track; superelevation of outer rail on curves; easements and runoffs of superelevation at ends of curves and points of compounding; maintenance of gage; adjustment of frogs, switches, and switch stands; vertical curves at breaks in profile.

Passage of Time.—When cross-ties, switch-ties, and bridge-ties have reached the point when they should be renewed; condition of timber in bridges and buildings on account of age; deterioration and renewal of ballast; deterioration of insulation on wires and cables; deterioration of underground pipes.

These are some but not all of the physical problems which at one time or another confront the foreman and demand some solution or palliation.

In addition the foreman must be posted on the operating rules, conditions and practices affecting the running of trains; he must acquire a general knowledge of the peculiarities of equipment and their effects on his work; he must become familiar with the requirements as to the shipment, receipt, and inspection of material; he must learn to make repairs and renewals and do his work without

unnecessary interference with the movement of trains,—the most of it must be done without any interference; learn to discriminate carefully between the many calls for his attention so as to take care of what is most important from an operating or maintenance standpoint, as the case may be; and maintain amicable relations with the railroad company's neighbors, his inferiors and superiors, and his fellow employees.

Is it any wonder that to attain a good working knowledge of the treatment of the major portion of these items requires years of experience? And is not recognized efficiency in the premises worthy of being classed skilled labor as much as any journeyman mechanic? And what do you suppose the compensation for such service is? From the statistical reports of the Interstate Commerce Commission, the section foreman averaged for 1903–1904 as little as $1.78 per day, or $53.40 per month. We know that track foremen have received as low as $40 per month and as high as $85 and $90 per month, according to location. It is, of course, understood that foremen of labor of other classes than trackmen receive generally better compensation.

The average wage of section foremen of $1.78 per day does not compare very favorably with other mechanics' wages of from $2 to $5 per day, according to trade and location. Attempts have been made by section foremen sporadically to form organizations to compel better wages. The necessary isolation of the men has, however, generally defeated such movements. It is manifestly difficult to secure cohesion and concentrated action when there is only one man for every six miles of railroad and one man per one hundred square miles of country.

This unfavorable comparison in the matter of compensation, coupled with inability to force recognition by combination, is driving the younger men into other occupations as laborers and apprentices. The effect of this is beginning to be painfully manifest among the foremen now in service. We see them growing old with little or no material developing to fill the gaps which are now upon us and which will come with increasing frequency in the future. Unless the logic of the situation is realized by those in authority very shortly and the disparity of wages corrected voluntarily, it will be, and is already, a serious problem to know which way to turn for men willing and competent to continue the work of the maintenance of our railroads. They will, of course, be maintained after a fashion, but on a gradually descending scale of efficiency.

So much as to the foreman's training; now as to his work. He is almost invariably given charge of a certain kind of work on a definite section of track or road and is held responsible in one way or another for nearly everything that can happen or be done within the limits of that section. The manifold duties and responsibilities can best be indicated by reciting a number of features for which the track-foreman is usually held accountable. He has charge of track and other repairs, including the inspection and safety of track, bridges, ditches, banks, slopes, road crossings, and fences. He engages in work personally and sees to it that the men under him are competent and perform their work and duties properly. He administers discipline for failure, neglect, and misconduct. He keeps all necessary records of the time of the men employed under him and all materials handled and used. He is required to be familiar with the rules governing the movement of trains; to have a proper time-table and be familiar with the times of trains over his section. He must have a reliable watch and check its running daily with standard time.

He must keep on hand a supply of the various signals for use in case of danger as prescribed by the rules governing trains, and must in no way obstruct the track or remove a rail, frog, switch, etc., without first displaying proper signals, and this generally without interference with the movement of trains. He must know, when flagmen are sent out to protect trains, that the proper signals are displayed, and he is held personally responsible for the safety of trains in this respect. He must watch carefully the signals carried by trains, also the make-up of trains, and must be constantly on the lookout for extra trains of which no notice is given. He must keep watch of points where obstructions are likely to occur, remove combustible material from the vicinity of tracks, bridges, and buildings, extinguish fires, watch the telephone, telegraph, and signal wires, and keep poles in proper position.

He reports any derangement of the wires, and assists the telegraph linemen and other employees in the line of their duties when necessary. He keeps close watch of the water supply, sees that it is in proper working order as far as he can, and reports failures and defects when he cannot remedy them himself. In case of wind, rain, sleet, and snow-storm and soft weather he details all hands, or as many as may be necessary, to watch the road and take every precaution possible to prevent accident. He sees that all culverts or other openings in the roadway for the passage of water are kept free from driftwood

or other obstructions, making special examination of such structures after each storm, and makes report at once of any wash or undermining that may have occurred.

He must not do or permit to be done any work that will obstruct the track during fog or storm except in cases of emergency. He must see that all grass, weeds, and brush on the right of way and property are cut and disposed of at the proper time. He picks up and makes disposition of all material dropped from passing trains. He permits no material to be piled close to main-track or side-track or elsewhere in such manner as to interfere with the safety of trains, employees or the public.

Hand-cars and hand-trucks must be run with great caution, always keeping lookout for extra trains, and providing full signal protection where circumstances and instructions require. He must not run his hand-car or hand-truck within a specified time before the time of any regular scheduled train. He must not permit these cars to be used except in the service of the railroad, and no one must be permitted to ride on these cars except employees in the performance of their duties, unless provided with written order from proper authority.

He must not operate his cars on Sundays or holidays, or after dark, or in foggy or stormy weather, without special authority, and then only with proper protection. His cars must not be attached to trains in motion, and when not in use must be secured so that they cannot be moved to endanger the safety of trains.

He must investigate and report on injury or damage to stock, property, or employees, or other persons. In case of accident he must render all assistance in his power. He must permit no encroachment of any kind on the railroad property. This refers to encroachment of whatever nature,—wires, drainage, trespass, buildings, fences, pipes, pollution, etc. In case of attempted encroachment notice must be given to desist and the encroachment removed, making proper report of the occurrence.

He must see that all road, bridge, tunnel, crossing, and other watchmen under his care are provided with necessary signals and supplies, and know that they are competent and perform their duties properly. He must know when he goes on duty that all trains due are past, and if not, must be governed accordingly.

He must make no change in tracks that will interfere with signals, telegraph, buildings, bridges, or other structures, without the knowledge and coöperation when necessary of the other departments con-

cerned. He must inspect his territory frequently, know the condition of his tracks, and make the necessary adjustments and repairs, noting the condition of bridges, buildings, signals, etc., and notify proper party in case defects which should be corrected are discovered. He should keep close watch of the movement of trains and report any violations of the rules noticed. He should keep in touch with what is going on in the territory through which his section extends and report on any improvements, projects, or other matters likely in any way to affect the railroad property, policy, or operation. In addition, he furnishes help for miscellaneous work at stations—both freight and passenger—to take care of unusual matters or emergencies.

Such, in a general way, are the duties of a section or track foreman. Other maintenance foremen have many duties in common with those just recited, variation being made of course as to kind of work done. The result is, however, the same in each case,—the foreman is responsible absolutely and clearly for certain definite things.

This responsibility, whatever else happens, never ceases day and night, summer and winter, year in and year out. The mere recital of the many items of responsibility is of itself quite formidable. To live with them and under them for a term of years; to have them brought home to you one at a time or in groups by actual happenings,—some of these happenings causing loss, damage, personal injury, and death; to be haled before the courts in connection with litigation of claims for loss, damage, and personal injury, and be examined and cross-examined as to these many items of responsibility and their bearing on the case in hand,—truly the responsibility does not lessen. These things which on first acquaintance seem more or less perfunctory become, after lapse of time and perhaps bitter experience, burned into the understanding, as it were, and not to be forgotten.

Such is the burden of the foreman—in times of flood and high water; in extremes of temperature; in blizzards and snow-storms—felt most keenly when others seek shelter from the elements; and with all this, inadequate compensation to him and the men under him.

At times the force available for doing the work required decreases either through inability to hire the necessary laborers on account of the low rate of pay, or through actual reduction of force to meet some necessity—temporary or otherwise—for decreased expenses.

In addition to the limitations as to the kind and amount of labor provided, the materials furnished for repairs and renewals are also restricted, sometimes temporarily and sometimes for considerable periods. Under such conditions the material that is furnished is often so grudgingly provided that it can almost be inferred that it is desired to let the property deteriorate.

How, then, does he get along? The work which is required to be done and for which he is responsible can be divided into a number of classes according to importance. Let us name a few: Necessary for safety. Necessary for operation. Necessary by statute and ordinance. Necessary by deed requirement. Necessary for proper maintenance. Necessary for economical maintenance. Necessary for appearances. Necessary for improvement as to any one of the above. Necessary to please the public. Necessary to please individuals of the public. Necessary to please officials of the railroad. Necessary to please individual railroad officials. When labor and materials are limited, the judgment of the foreman must assert itself and eliminate such items of work from his program as cannot be accomplished. This elimination takes place even in violation of some of the many rules and instructions. As the rules and instructions can be divided into classes similar to those just mentioned in connection with work to be done, these violations necessary to keep the quantity of work within the labor available need not approach matters affecting safety, unless the limitations as to force and material are severe and long-continued.

It is on this principle that the expense of maintenance of way and structures as between different roads and as between different times on the same road fluctuates within such wide limits. It is safe to say in this connection that no road ever puts enough money into its maintenance to satisfy all the demands as to necessary work classified above. This elimination of certain kinds of work as necessities is frequently practised, and is many times carried to the point where the relationship between the road and its patrons, neighbors, and the public generally, is severely strained. Where this policy is followed, and it is not recognized by the general officers of the road that certain classes of work cannot be accomplished, insistence that all the items of work be performed notwithstanding results in the relations between the road and its employees being also strained.

What has this fixing and concentration of responsibility done for

the railroads? It has resulted in the maintenance of the track of the railroads in the United States being accomplished with the labor of about one trackman per mile of track. When it is studied, such a result is quite wonderful. One man working a little over three hundred ten-hour days per annum can replace the necessary cross-ties, rails, fastenings, frogs, switches, ballast, cut the grass and weeds, handle all the required material both new and old, keep the ditches open, adjust the fastenings, maintain the gage by respiking and adzing, raise a portion of the track, put in ballast, raise joints, surface track, maintain line of the rails, remove snow and ice, and take care of the hundred and one things demanding attention! It is certainly an herculean task. Considering the work to be done, we would undoubtedly think its accomplishment impossible did we not know that it is actually done regularly. Marvellous though it is it is a fact, and it is made possible by what has come to be called "organization."

The foreman and his men are the first and most important part of this structure. They are the foundation. On this as a base all organized effort is conducted. Without it is chaos and retrogression to the primitive state; many men many minds—everyone for himself. With it, order and concentration of effort. The laborers, mechanics, or other classes of employees are the units. The foreman is the agent which directs them. He sees to it that there is no effort wasted; that it is bent to the doing of only one thing at a time; that the units meet no outside interference.

Under such circumstances the duties of the units become very simple. They have but to follow the instructions of the foreman implicitly. All their energies can then be concentrated on doing that in which they are most skilled. The foreman and his men become collectively an industrial unit—a veritable giant, however, as compared with the original unit.

It is pertinent at this point to consider how many units one man can effectively direct and control. Experience seems to indicate that from five to fifteen represents the range according to ability. Cases occur where the greater number is exceeded. They are, however, rare. When the number of units is greater than fifteen and often when less than fifteen, a sub-foreman—in fact if not in name—will be found almost invariably. So that very large gangs if at all efficient are made up of smaller groups in one way or another, which are, in their last analysis, still foreman and men.

To illustrate the effect of organization on the efficiency of labor, this example will serve. The work was loading a certain class of material on railroad cars from the track level. The cars were placed on a long track, the material being piled alongside. A force of about one hundred men under one foreman loaded the material with shovels for a period. Later another group of men of about the same number were put at the same work. In this case there was a foreman for less than every ten men. The laborers were paid the same hourly rate in both cases and were of the same class of men. The result was that notwithstanding the fact that the wages of the numerous foremen went into the labor cost of handling the material, the additional quantity loaded in the latter case was enough to keep the cost per ton of loading down to little more than half what it was in the first case. This is, of course, rather an unusual comparison. It shows plainly the benefit of closer supervision and control.

As soon as the amount of work to be done requires more workmen than one foreman can direct and control with efficiency, other foremen must be selected and placed in charge of other gangs or groups of men. It then becomes necessary to organize these unit groups or gangs by placing a general foreman or overseer in charge of them in the same way that the original foreman was placed in charge of the workmen, and for precisely the same reasons,—fixing of responsibility, concentration of effort, and elimination of conflicting instructions and conditions.

These overseers in railroad maintenance work are called general foreman, roadmaster, or supervisor of track, as the case may be for the track labor; general foreman, master carpenter, superintendent, or supervisor of bridges and buildings, for the bridge and building employees, and general foreman or supervisor of signals where the number of signals and signal repairmen justify a separate grouping.

This step has created a still larger industrial unit ranging in size from forty or fifty men to five hundred or six hundred men according to local necessity.

Up to this point nearly all railroad organization is identical. After this point variations creep in according to whether the departmental or divisional organization, so called, is in force or preferred. Of these the divisional organization more nearly accords with the foreman and gang principle. With the divisional system all the various activities—maintenance of way, maintenance of equipment, conduct-

ing transportation, and a number of other smaller interests—are or should be gathered together and put in effective charge of one man so that all the interests which exist side by side, cover the same territory, and are dependent upon each other, can be harmonized and wielded as one immense engine of effort. This last and much enlarged group ranges in numerical size from several hundred men to from five to ten thousand, and in common parlance is called a "division," and the man in charge is given the title of superintendent.

As the territory covered enlarges, the same process of grouping continues until we have general superintendents and finally a general manager. As this ascending scale develops, the same grouping and fixing of responsibility and unification of effort follow invariably through all the stages. It is therefore quite apparent that the original group of foreman and his men is thoroughly typical of railroad organization generally and maintenance organization specially.

After all has been said it remains that the foreman and the men under him in the original grouping are the most important part of the whole structure. It is the foundation on which the whole is reared. Let the foundation be bad and the whole structure is defective. Let the foundation be good and the whole structure is sound.

It will not be amiss to call attention to the similarity between the foremen and the engineer. Both start with material and labor and by proper combination produce the finished work. Both are by training and should be by nature leaders of men. The same necessities produced both. The foreman is an engineer. The engineer is a foreman. The largest success in life as far as engineers are concerned seems to fall to those who can organize and lead men. Many never get beyond the consideration of things. Things without men are as nothing. Let us study men. Let us be foremen and we will be engineers. All honor to the foreman!

DISCUSSION.

Benjamin Franklin.—I have been particularly struck during my own experience with the difficulty of obtaining foremen of experience, and I have nearly always found that, as Mr. Kapp observed, most track foremen are old men. In personal contact with them, I have found that I could learn a good deal, especially in regard to the alignment of track, superelevation of the outer rail, and the fine art of laying special work, and I think the foreman deserves more credit for this phase of railroad maintenance than the engineer.

William Gowie.—I think there are quite a number of things about which the foreman knows nothing and in which the engineer is trained. I think it requires a first-class engineer to handle most railroad matters which may be

classified under technical headings. For instance, I once asked a track foreman how much expansion he allowed for that hot day (the temperature was 105°), and he said: "We don't allow nothin'; we just push it together." Of course he was an Irishman. And I would like to know how many of these foremen know anything about stress and strain, temperature, motion, friction, etc., etc. Speaking generally and as one who has had experience with foremen, I would also like to say that there are very few foremen who can give you all the information you need. Their motto is generally: "Do the best you can." I would like to know whether they are taught any technical knowledge. I have watched very carefully to see how much they gauged a track going around a curve. They have no definite method of determining the elevation. If the track looks slightly low they step off a hundred feet or so and take another look at it, and if it looks out of proportion to the rest of the track, they adze it up.

Mr. Kapp.—About superelevation of the outer rail: I believe that track foremen, as a body, know more about the proper elevation of the outer rail than do engineers. Engineers have developed the theory of the outer rail on the basis of centrifugal force. The foremen developed their theory of elevation from watching the trains go around the curves. Many a foreman will stand around a track while the cars go by, and if the cars sway or oscillate he knows the job is wrong, and he works at it until he gets it right. As to the amount of elevation, it is always a compromise. The theoretical elevation of the outer rail is, ninety-nine times out of a hundred, wrong, in the case in hand, and the foreman can generally make a better adjustment than can the engineer.

As to line, many foremen can put up better track and line than engineers. It has been my pleasurable experience to be able to teach foremen how to provide good line. I have also heard a good many tales about the poor line that engineers have given, and a good many foremen dislike very much to see a man come along with an instrument and tape line. The method I have pursued is one of rule and string. The theory of curvature is, that it shall be uniform, or gradually increasing or decreasing, and all the aligning that need be done around a railroad can be accomplished by the use of a 2-foot rule and a string about 100 or 125 ft. long. Stakes can be set out so that you can see before you start just how much a track is to be thrown, and all the obstacles to a correct line can be eradicated, and the cost can be reduced to a small amount, as compared with the cost of a corps of engineers to run a line as they think it ought to be run. I have seen foremen get very angry because some one attempted to tell them that he could better the line on a curve, and I doubt if many engineers could do it better than those same foremen, and put up superelevations and easements. I know of several 6-degree curves where trains are operated at speeds of sixty and sixty-five miles per hour without occasioning any comment or unpleasantness, these curves being maintained by foremen without the assistance of engineers.

Replying to the question as to what kind of men make the best foremen, I think that it has been the custom on several railroads in appointing foremen to select them from among their carpenters, they, as a rule, having had a range of experience which makes them very valuable.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, September 15, 1906.—President McBride in the chair. Eighty members and visitors present.

The Nominating Committee for the year 1906, as nomiated by the Board of Directors, was confirmed as follows: S. G. Comfort, Chairman; H. T. Campion, Horatio A. Foster, C. H. Ott, and W. B. Riegner.

The Secretary announced the death of Mr. E. T. Hannam, active member on August 18. Dr. Henry Leffmann read a paper on "Denatured Alcohol: Its Manufacture and Some of its Applications."

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Adjourned Meeting, July 2, 1906.—Present: President McBride, Vice-President Devereux, Directors Dallett, Dodge, Head, Loomis, and Quimby, and the Secretary and Treasurer.

The report of the Treasurer for the month of May was read and accepted as follows:—

Balance April 30, 1906	$4958.00
May Receipts	185.00
	$5143.00
May Disbursements	536.21
Balance May 31, 1906	$4606.79

It was moved and carried that Mr. H. T. Campion be selected as a member of the Nominating Committee in the place of Mr. Miller, who had declined the nomination.

It was moved and carried that the salary of the clerk be raised from $40 to $50 per month, dating from July 1.

The House Committee made a report as follows regarding the suggestion that a restaurant be established in the Club House. It was moved and carried that the report of the House Committee be filed and that further consideration of the matter be dropped:

"The House Committee would make the following report to the Board of

Directors regarding the proposal to install a restaurant in the cellar of the Club House and to make arrangements with a caterer for furnishing refreshments. The Committee would report that they have estimated that it would cost about one thousand dollars to fit up the restaurant and that since the heaters would need to be removed from the cellar, it would be necessary to heat the entire building with steam, which would require an additional expenditure of about one hundred dollars per annum. The project would also require that a long term lease should be made of at least five years, and that the Girard Estate will not consider except on the basis of an increased rental, the increase to be about two hundred dollars per annum. Under these conditions your Committee considers that the project is inadvisable and would therefore recommend that further consideration of the matter be dropped."

The Secretary read a communication from Select and Common Councils of the City of Philadelphia, asking for the appointment of an expert to serve as a member of an advisory board on the subject of filtration of the city water. It was moved and carried that when the Councils appoint their expert, the President of the Engineers' Club be authorized to appoint an expert.

Regular Meeting, September 15, 1906.—Present: President McBride, Vice-President Devereux, Directors Dallett, Dodge, and Head, and the Secretary and Treasurer.

The report of the Treasurer for the months of June, July and August was read and accepted as follows:

Balance May 31, 1906	$4606.79	
Receipts:		
June	517.50	
July	410.00	
August	27.50	$5561.79
Disbursements:		
June	742.77	
July	706.50	
August	309.38	1758.65
Balance August 31, 1906		$3803.14

Mr. W. P. Dallett was appointed as a delegate to the dedication of the new building for the engineering department of the University of Pennsylvania, in response to an invitation from the University.

ADDITIONS TO THE GENERAL LIBRARY.

FROM AMERICAN IRON AND STEEL ASSOCIATION.
Annual Statistical Report for 1905.

FROM BOSTON SOCIETY OF CIVIL ENGINEERS.
Constitution, By-Laws and List of Members, 1906.

FROM UNIVERSITY CLUB.
University Club of Philadelphia, 1906.

FROM A. GIBB MAITLAND.
Bulletin, Nos. 21 and 22.

FROM EMIL L. NUEBLING.
Forty-first Annual Report of the Board of Water Commissioners, Reading, Pa.

FROM ROCHESTER ACADEMY OF SCIENCE.
Proceedings, Vol. III, Broch. 3.

FROM DOCKHAM PUBLISHING CO.
United States Club Register, 1906.

FROM UNIVERSITY OF PENNSYLVANIA.
Proceedings of Commencement, 1906.

FROM LIBRARY OF CONGRESS.
Select List of Books on Railroads in Foreign Countries.

FROM DELAWARE COUNTY INSTITUTE OF SCIENCE.
Proceedings, Vol. I, No. 4.

FROM GEOLOGICAL SURVEY OF OHIO.
Salt Deposits and the Salt Industry in Ohio.
Bulletins Nos. 4 and 5, bound.

FROM FIRE INSURANCE SOCIETY OF PHILADELPHIA.
Proceedings of Fire Insurance Society of Philadelphia, Vol. IV.